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THESIS

LIFE CYCLE MANAGEMENT OF BAHRAINI AMIRI AIR FORCE F-16 AIRCRAFT

by

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June 2001

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This thesis presents a general scheme for implementing Life Cycle Management (LCM) in the Bahrain Defense Force (BDF) and Bahrain Amiri Air Force (BAAF), with special attention paid to LCM issues for the F16 weapon system. The current situation of Bahrain, as well as the history and current challenges facing the BAAF in managing its F16's, are presented. Those challenges are to reduce the Total Ownership Cost (TOC) of the F16 fleet to the bare minimum without disturbing the defensive posture of the BDF and BAAF.

The related concepts of LCM, TOC, and Reduction in Total Ownership (R-TOC) are discussed in general, and also in the context of the BAAF F16 force. A feasible method of applying these methods to the BAAF's current situation is then presented in the form of recommended policies, procedures, roles, and responsibilities. Processes and procedures for use by both the BAAF and its suppliers in the management of resources are also recommended. These address all phases of the F16 life cycle (development, deployment, operation, maintenance, management, and retirement).

The advantages associated with developing data and management systems for identification and tracking of the Total Ownership Cost (TOC) of the BAAF F-16 are likewise emphasized. They allow management to make effective trade-off decisions regarding the acceptance or rejection of modifications and upgrades.

To demonstrate the method, an assessment of BAAF F16 Operations and Support (O&S) costs are also provided, with some of the data being generic and unclassified. Analysis of these data suggests significant cost savings to the BAAF are possible through changes in operational and support procedures, and specifically, through consolidation of support operations, elimination of some functions and consolidation of others. The implementation of these LCM procedures can be applied to other aircraft types in the BAAF, including the F16's replacement.

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LIFE CYCLE MANAGEMENT OF BAHRAINI AMIRI AIR FORCE F-16 AIRCRAFT

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I. INTRODUCTION

A. BACKGROUND

In an era of rapidly changing technology, every military establishment and culture faces major problem. That problem is not what new weapon system should be bought, but how best to reduce the Total Operating Cost (TOC) of existing weapon systems. The difficult question that keeps decision makers and Life Cycle Management (LCM) on edge is in how to manage and maintain that current system during its operation life until disposal or retirement in such a way as to reduce its cost, i.e. to save money and time. Each country is faced with rising costs in maintenance. That cost must be attacked vigorously and continuously through LCM. Only with the reduction in TOC (RTOC), can any country start to budget for new weapon systems. Weapon systems must be reliable, maintained, available, and ready for any commitment counter to any threat and to deal with that threat at the right time, in the right place.

The decision to field a new system requires a commitment to support that system throughout its life cycle. That life cycle is predicated on many things, such as how many flight hours per year per aircraft (in the case of the Bahrain Amiri Air Force (BAAF). Decisions to develop, procure, and support new systems are based on many factors, one of which is the projected cost of the systems over their operational lifetime.

When the state of Bahrain, represented by the Bahrain Defense Force (BDF), decided to procure a fighter aircraft, it went through several stages of investigation to evaluate various aircraft models. These models were the F-15, F-16, F-18 (all US), the British Tornado, the French Mirage 2000, and even a few Russian types. Maintainability,

reliability, supportability and the potential for future upgrade were the criteria that led the BDF to select the F-16, Block 40 Fighting Falcon. So, in 1990, the State of Bahrain became the fifteenth operator of the Fighting Falcon and the first air force in the Arabian Gulf region to adopt the F-16, thereby forging ahead at an astonishing pace. After the procurement of the F-16 Fighting Falcon by the BDF, the Bahraini Amiri Air Force (BAAF) has faced several critical requirements for it's support.

This thesis focuses on and studies the problems that are facing the BAAF F-16 Falcon program (Peace Crown I and II). These problems are Logistics, Upgrades and Technology, Training and finally Manpower. The intention is to give the reader an idea on how these criteria can play a major role in determining the readiness, maintainability, availability, and reliability thereby supporting the type of missions of the BAAF F-16 in wartime as well as in peace. A discussion regarding the effectiveness and impact on the policies of buying, not only new weapon systems, but also their influence in determining the source of supply regardless of the cost putting in consideration the time factor for procurement.

The Total Ownership Cost (TOC), once referred to as the Life Cycle Cost (LCC) of a system, can be conveniently divided into several phases. (1) research and development, (2) production, (3) operating and support (O&S) and (4) the disposal. In this thesis, the preponderance of attention will be on the O&S phase. This is due to the fact that the F-16 weapon systems for the BAAF have already been procured. It will also identify a feasible approach and suggestions that can help in effectively managing the BAAF F-16 until disposal or retirement time.

B. RESEARCH OBJECTIVE

The primary objective of this thesis is to formulate a general scheme suitable for managing the life cycle of the F-16 aircraft fleet for the Bahraini Amiri Air Force (BAAF) through the rest of its operational life. This scheme can also has the ability to manage, control and deal with the ongoing and the expected future circumstances of the Total Ownership Cost (TOC) of the Bahraini Amiri Air force (BAAF) F-16 aircraft and provide analytical tools that help reduce it. It must be approached in a wise way to save money and time to ensure the readiness, maintainability, reliability, supportability and availability of the aircraft for war and peace.

C. RESEARCH QUESTIONS

- What is the current situation and national strategy of Bahrain?
- What is the military capability that will be need by Bahrain in the future?
- How does the current F-16 aircraft contribute to execution of military strategy?
- What is the history of F-16 program in Bahrain?
- What is the current literature about Life Cycle Management and its concept?
- What are the three elements that comprise the Total Ownership Cost (TOC) and what sub-elements are included in each of the three major categories?
- How well do various methods of Life Cycle Management fit other current circumstances of Bahraini F-16 aircraft?

- What are the milestones and phases that accompany any acquisition program and what are the decisions affecting an acquisition?
- Define Total Ownership Cost (TOC) and what are the objectives of the TOC?
- What are the elements of TOC?
- What are the elements that make up the O&S cost?
- What does the cost model mean? What are the types of the cost models?
- What is the most useful model to manage the Bahraini F-16 aircraft Life Cycle?
- What is the first step use by the analysts in determining the TOC?
- What are cost drivers and how they are determined?
- What are the key decisions for managing Bahraini F-16 aircraft Life Cycle & when are these expecting them to occur?

D. RESEARCH SCOPE

The scope will include:

- A review of a current situation of Bahraini F-16 aircraft & its mission
- An in-depth review of the Bahraini F-16 aircraft
- A review and evaluation of conceptual model of Bahraini F-16 Life Cycle Management
- A proposed model for managing Bahraini F-16 through the rest of their Life Cycle

- Present a generic cost analysis of F-16 fleet TOC in a manner that BDF & BAAF can continue its LCM

- Identify and analyze the cost drivers that constitute the biggest bear on the BDF budget and try to find the solutions that minimize their cost via implementing the LCM

- The thesis will conclude with a recommendation: a general planning guide for managing the Bahraini F-16 aircraft

E. METHODOLOGY

The methodology defines the activities that are needed to build a system, the Interfaces among those activities, and the products created as a result of those activities.

The methodology used in this thesis research will consist of the following steps:

- Conduct a literature search of books, magazine articles, CD-ROM systems, and other library information resources

- Conduct a thorough review of the current situation of Bahrain as a nation in the world and in the Gulf Cooperation Council (GCC)

- Conduct a thorough review of the history of Bahrain Defense Force (BDF)

- Conduct a thorough review of BAAF history and its establishment

- Conduct a thorough review of the F-16 program history in Bahrain

- Conduct a thorough review of the current literature about life cycle management and its concept

- Analyze the various methods of life cycle management that fit the current circumstances of Bahraini F-16s
- Identify the TOC elements and what each element includes
- Conduct a thorough review of the TOC development process
- Explore the other alternatives for the repair cycle process in terms of costing
- Identify total ownership cost models for BAAF F-16 aircraft
- Identify and analyze the cost drivers that create the greatest cost during the O&S cost and find solutions that may reduce or save assets
- Determine the future development of the BAAF

F. ORGANIZATION OF THE THESIS

Chapter II, BAAF History and Present Situation. This chapter organize as follows: (1) Introduction to Bahrain as a country, (2) The stages and developments of establishing the BAAF, (3) Process of Acquiring the F-16.

Chapter III, Life Cycle Management, describes life cycle management as follows: (1) Definition, (2) Purpose (3), Overview (4), Process of acquisition, (5) Milestones and phases in the acquisition life cycle, (6) Decisions affecting an acquisition and (7) Chapter Summary.

Chapter IV focusing on the Total Ownership. This chapter starts as follows: (1)Definition, (2) Objective, (3) Description of TOC elements, (4) Methodology, (5) Cost models and (6) chapter Summary.

Chapter V addresses the BAAF F-16 Total Ownership Cost. This chapter organize as follows: (1) Description of ground rules and assumptions, (2) Procurements, (3) Operation & Support, (4) Disposal and (5) TOC Summary.

Chapter VI focusing the BAAF O&S cost drivers. The chapter starts with (1) a brief description of cost drivers, (2) Identification of cost drivers, and (3) Discussion.

Chapter VII, addresses: (1) Conclusion of the thesis and (2) Recommendation.

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II. BAAF HISTORY AND PRESENT SITUATION

(The defense of the country is the defense of all that we have inherited in terms of values, traditions and our plentiful land as well as our system of faith in God and respect for the individual).
... H.H. Shaikh Hamad Bin Isa Al Khalifa, the Amir, the Supreme command

A. INTRODUCTION TO BAHRAIN

The Arab Gulf abounds in islands. Important among them are the islands of Bahrain. Bahrain is made up of an archipelago consisting of a total of over 33 islands forming a rough triangle. To its west and north-west lies the Kingdom of Saudi Arabia, to the north the Arab Gulf and to the east and south the state of Qatar. The total area of its territory is 687 square kilometers. Its population is approximately 531,000.[1]

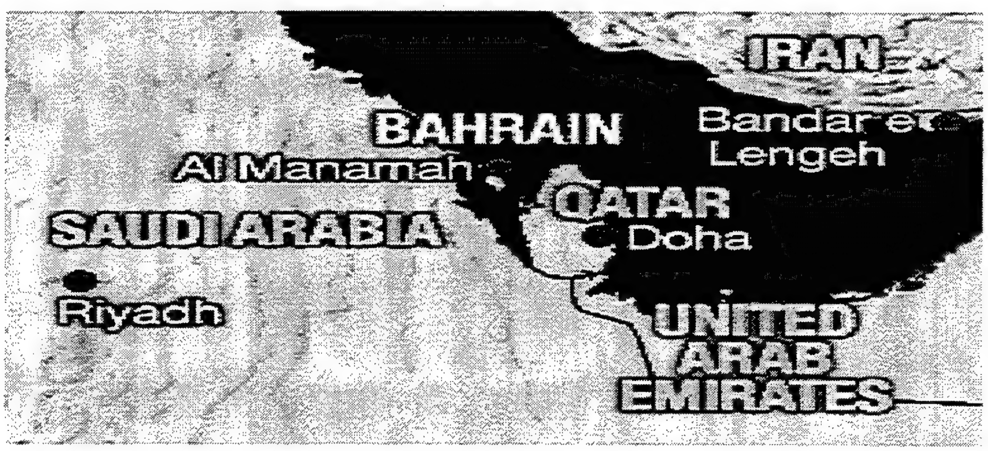

Figure 1. The Arab Gulf

[1] Al Khalifa H, First Light: Modern Bahrain and its Heritage, UK, Kegan Paul International.

Frequently called the *Pearl of the Arabian Gulf,* Bahrain has a history of more than 5,000 years of civilization[2] from the mists of time to a vibrant present under a stable and prosperous government.

Bahrain is one of the most densely populated island countries in the world. Approximately 140,000 people[3] reside in the capital city of Manama. Arabic is the official language, but many citizens also speak English. Bahrain is sometimes referred to as the Switzerland of the Middle East, because of its many banks and financial centers. The country has one of the lowest elevations in the world. Its highest point reaches a mere 134m or 440'. Bahrain's main exports are aluminum and petroleum.

While Bahrain is relatively small in land area, population and resources, it has achieved a high level of social and economic development in a short period. The road network, international airport, telecommunications, public services, medical facilities and university are all recognized as being among the best in the world.

B. STAGES AND DEVELOPMENTS OF ESTABLISHING THE BAAF

1. Background

In September 1968, H.H Shaikh Isa Bin Salman Al Khalifa, the late Amir and the Supreme Commander established a defence organisation which was known at that time as the National Guard. H.H the Amir appointed H.E Shaikh Hamad Bin Isa Al Khalifa as Commander of the National Guard. The name was later changed by an Amiri decree to Bahrain Defence Force (BDF). The formation of the BDF was called by H.H Shaikh Isa Bin Salman Al Khalifa, the Amir as a result of the vacuum, which was expected after the British withdrawal from the region, to protect the country, to ensure its security and

[2] http://www.bahrain.gov.bh/English/Bahrain/Introduction.asp

[3] http://www.zorona.com/English/countries/bahrain

stability, and also to co-operate with its neighbour states in protecting the region against dangers and threats. *BDF goals* are[4]: (1) Protect the country's security and sovereignty and fight against any enemy forces. (2) Support internal security and provide assistance whenever called. (3) Join GCC cooperation. However, in an interview published by the Lebanese paper "Al Anwaar" His Highness Shaikh Hamad said:

> (The most important role which our Defense Force would be called upon to play will be the "civilization role" ... I believe that when an army is built up on sound scientific principles it becomes a factor of stability)[5].

The stages of establishment and building the Bahraini Air Force were not easy. It encountered many challenges and difficult circumstances before it reached a good reputation in the international community. The processes and the stages of these developments are as follows:

2. The Air Wing

The foundation of the Bahrain Amiri Air Force (BAAF) came by order of H.H. Shaikh Hamad Bin Isa Al-khalifa the beloved Amir and Supreme Commander with the formation of an Air Wing on the 8th of May 1976 to complement other formations and units already in service in the B.D.F. The formation of BAAF was preceded by several studies conducted of the requirements of the Bahrain Defense Force, as dictated by geographical location, the strategic position of the country and the standards achieved by advanced countries in this field.

In view of the strategic requirements the national authorities initially adopted a project for equipping the air wing with helicopters. The reasons behind that were[6]:

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[4] Major A. A. R. MALALLAH AL SABT, Model for Purchasing and Inventory for Bahrain Defense Force, Unpublished Masters Dissertation, Royal Military College of Science, July. 1998.

[5] Leader and the Force. http://www.bahrain.gov.bh/English/books/Leader_and_Force/index.asp

- Potential and capacity for rapid movement
- Combat reconnaissance and rescue under various conditions
- Capability of challenging hostile Armour
- Great maneuverability and low-level flying capability, which kept it away from detection

The tasks assigned to the air arm were numerous and important: (1) supporting the ground forces by quickly transferring equipment whose movement over ground in high mountains or water surfaces or sand stretches is difficult, (2) defense of the air space and boundaries of the country on land, (3) defense of territorial waters in conjunction with the Navy.

On 26 October 1974, the BDF sent the first batch of pilots to the King Faisal Air Academy in the Kingdom of Saudi Arabia to study aerospace sciences. To prepare the necessary personnel to fulfil all the needed technical, engineering and maintenance functions, the first two groups of NCO's were sent to the United Kingdom in 1974 and 1975 for basic training. Once all the essential preliminary preparations had been completed, the first helicopters for the BAAF arrived in Bahrain on 25 February 1977.

On the 5th of February 1980, which coincided with the 12th anniversary of the formation of BDF, the late Amir H.H. Shaikh Isa Bin Salman Al-Khalifa honoured the BAAF when it received its banner from the benevolent hands of His Highness during the ceremony and parade which were held on the runway of Al-sakhir airfield.

[6] http://www.bahrain.gov.bh/English/books/Leader_and_Force/chap03_01.asp

At the beginning of May 1979, construction of Al-Riffa Air Base started and on the 4th of September 1979 the operational helicopter squadron arrived at the new base.

On the 26th of April 1982, the late H.H. Shaikh Isa Bin Salman Al-Khalifa officially opened the Al-Riffa base which was a landmark event in his reign and one that marked his gracious and bountiful leadership.

3. Air Force

Sheik Isa Air Base is home to the BAAF and is located on the shores of the Arabian Gulf in southern Bahrain. It hosts the BAAF Fighter Wing and the two squadrons that comprise it. The 1st Fighter Squadron operates twelve Block 40 F-16s alongside twelve F-5E/F Tiger IIs from the 6th Fighter Squadron. (Any visitor to this spacious, modern air base may not believe that Bahrain's air power capability less than fifteen years ago consisted exclusively of rotary aircraft.)[7].

In 1985 the Bahraini Air Force entered the road to high-performance fighters, and then immediately maneuvered to the fast lane. This entrance made a big jump in the field of improving Bahrain's arms and weapons by purchasing through US FMS *12 Northrop F-5 E/F* combat aircraft. With the acceptance of the F-5 aircraft in October 1985, the BAAF joined the jet age.

On 12 December 1985, His Highness Shaikh Hamad Bin Isa Al-Khalifa the beloved Amir and Supreme commander announced the arrival of a number of new F-5 fighter aircraft; marking a turning point in the history of the BAAF. The procurement of the F-5 aircraft supported the security of the country and modernised its air fleet in order to be able to respond to any possible overspill of the Iran-Iraq war.

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[7] http://www.codeonemagazine.com/archives/1999/articles/oct_99/octa_99.html

In March 1987, Bahrain ordered twelve F-16 aircraft through the U.S. FMS, and through a program which became known as Peace Crown. In 1990, the BAAF become the fifteenth operator of the Fighting Falcon and the first air force in the Arabian Gulf region to adopt the F-16. The BAAF had forged ahead at an astonishing pace[8].

On the 28th of May 1990, H.H Shaikh Hamad Bin Isa Al-Khalifa, the beloved Amir and Supreme Commander, paid an inspection visit to the BAAF on the occasion of the introduction of the F-16 fighter planes, in order to follow up the first construction phase at the Shaikh Isa Air Force. Under the patronage of H.H Shaikh Isa Bin Salman Al-Khalifa the inauguration ceremony of the Shaikh Isa Air Base, one of the most modern installations designed to accommodate new aircraft, took place on the 2nd of February 1993[9].

On June 22, 2000 Bahrain received the first of its new production F-16 aircraft today in ceremonies at Lockheed Martin Aeronautics Company. The aircraft is the first of 10 F-16s purchased under the Peace Crown II program. Col. Khalifa Al-Khalifa, Defense Attaché for the Embassy of Bahrain, accepted the first of the F-16s that will establish a new fighter squadron for the Bahrain Amiri Air Force (BAAF) at Sheikh Isa Air Base. The new F-16s will supplement the BAAF's existing inventory of 12 Block 40s (eight C model, four D model) that were purchased in 1987 and delivered in 1990.

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[8] Code One Magazine Archives, October 1999, Volume 14 No. 4.

[9] Implementations of B.D.F in the era of H.H Shaikh Hamad Bin Isa Al-Khalifa the Amir and supreme commander.

Bahrain has shown remarkable proficiency with the F-16, flying 167 combat sorties during Desert Storm only months after the introduction and delivery of the first F-16 to their air force[10].

Since its foundations, the BAAF has witnessed further efforts to develop and modernize in the field of fighter jets and all types of equipment and supplies such as the Black Hawk and Cobra Helicopters.

C. PROCESS OF ACQUIRING THE F-16

1. Peace Crown I

In March of 1987, the government of the Arabian Gulf nation of Bahrain signed a letter of agreement for 12 F-16C/D fighter aircraft (8 Charlies and 4 Deltas) under the *Peace Crown* Foreign Military Sales program. The first aircraft were accepted in March 1990, and arrived in Bahrain on the 23rd of May 1990 as shown in Figure 2.

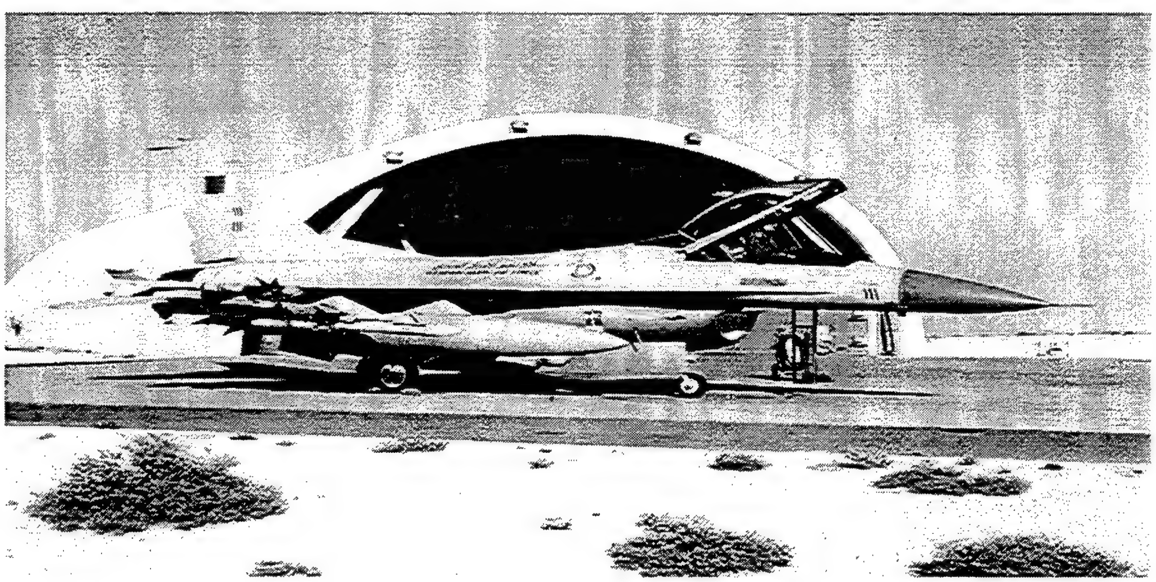

Figure 2. F-16C/D Fighter Aircraft.

[10] http://www.f-16.net/f16news.html?40

Since the F-16s for Bahrain were acquired under the Foreign Military Sales program, they were assigned USAF serial numbers. However, the aircraft only carry indigenous serial numbers. The aircraft numbers and air force legends on the fuselage sides appear in both English and Arabic[11].

2. Peace Crown II

In the early stages of what would ultimately result in Peace Crown II, Bahrain briefly negotiated with the US Navy about the purchase of 18 Ex-US Navy F-16s. The F-16Ns, withdrawn from US Navy aggressor training roles in 1994, would be exchanged for 8 F-5Es and 4 F-5Fs operated by Bahrain since 1985. The F-16Ns would supplement the 12 F-16C/Ds already in service, while the US Navy planned to use the Ex-Bahraini F-5s for the aggressor roles instead of the F-16s. This option was abandoned due to concerns about Bahrain's ability to support a non-standard air aircraft. Two alternative options were then proposed; either acquisition of ten new aircraft or the purchase of 20 upgraded aircraft. In either case the aircraft would be fitted with the avionics being installed in F-16s under the F-16 Mid Life Update (MLU) program.

Ultimately, the decision was taken to order 10 new F-16C Block 40 aircraft. The decision to buy new aircraft was apparently due to the commonality with Bahrain's other 12 Block 40s, lower overall cost, and longer service life[12].

The new production F-16 aircraft is basically the same Block 40 configuration as the aircraft from Peace Crown I, with some new equipment items added. These include a color cockpit TV system, APG-68 (V) 8 radar, and AIM-120 advanced medium range

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[11] http://www.f-16.net/reference/users/f16_bh.html

[12] http://www.f-16.net/reference/users/f16_bh.html

air-to-air missile (AMRAAM) capability. All of the new aircraft will be single seat F-16Cs. The Peace Crown II program is valued at $303 million, and completed delivery at the end of 2000[13].

[13] http://www.f-16.net/f16news.html?40

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III. LIFE CYCLE MANAGEMENT

A. DEFINITION

Life Cycle Management (LCM) is the structure used to insure proper decision processes are in place and utilized that influence the system performance, cost and usefulness. These processes must be based on full consideration of military operational requirements, economic affordability, and technical feasibility in order to obtain and maintain an effective weapon system.

B. PURPOSE

This study will establish the processes including policies, procedures, roles, and responsibilities governing the development, deployment, operation, maintenance, management, and retirement of BAAF F-16 aircraft within the Bahrain Defense Force (BDF). It is essential the BDF and BAAF understand the United States Air Force (USAF) LCM process because it applies to the development of the total weapon system and, equally important, to the modifications/upgrades that occur to the weapon system. In any LCM process regardless of the country, the manufacturing country , and in the case of the BAAF F-16, the United States, the country acquiring the weapon system or any modifications/upgrades must fully understand how the system or parts have been developed and managed. This then allows the BDF and BAAF to insure that what they are receiving is the best possible product. If there is no, or poor, LCM processes being used by the manufacturing country; it can only be assumed that the product will not be the best quality for the price paid.

C. OVERVIEW

1. Objective

The objectives of LCM are to:

- Deliver quality weapon systems which meet or exceed the Bahrain Defense Force (BDF) and the Bahraini Amiri Air Force (BAAF) expectations when promised and within cost estimates, from the system developer, through the acquiring organization to the BDF, and to the flying operation within the BAAF

- Deliver weapon systems that work effectively and efficiently within the current and planned information technology infrastructure within the BDF and the BAAF

- Deliver weapon systems that are affordable, maximize the ability to maintain, and are cost-effective to enhance for the life of the system

- Develop quality systems using an identifiable, measurable, and repeatable process. These systems apply to all areas of decision processes within the BDF and the BAAF.

- Establish an organizational and project management structure with appropriate levels of authority to ensure each system project is effectively managed throughout its life cycle and for the life cycle or the BAAF F-16 program.

- Identify and assign the roles and responsibilities of all affected parties including functional and technical managers throughout the system life cycle. This will include the relationships with the system developer, the acquiring offices, the offices responsible for supporting the fleet, and the personnel who operate and maintain the fleet of BAAF F-16 aircraft.

- Ensure that system requirements are well defined and subsequently satisfied at all times during the life cycle. These requirements can be expected to change with time as the system ages and the threat of potential aggressor fleets of aircraft change their equipment or tactics.
- Provide visibility to functional and technical managers for all systems resource requirements and expenditures
- Establish appropriate levels of management authority to provide timely direction, coordination, control, review, and approval of the system and the changes to the project throughout the life cycle
- Ensure project management accountability at all levels for the total life cycle of the fleet of BAAF F-16 aircraft
- Identify project risks early and manage them before they become problems during the initial acquisition of the system, and for all future proposed changes to the system

2. Function

Life Cycle Management (LCM) provides the mechanism necessary to develop data and management systems necessary to provide the best possible weapon system.[14] The result of good LCM is the ability to identify, track, and manage the Total Ownership Cost (TOC). Business practices associated with LCM increase the flexibility of both the BAAF and providers to handle their funds and resources. It provides the BDF and the BAAF an accurate picture of management results early enough to allow for corrections.

[14] Navy Information System Management Center (NISMC) Life Cycle Management (LCM) Review Handbook; April 1994, Section 1.0 Introduction.

Included in the LCM is the management of the TOC, including the true costs of support requirements. This allows them to make effective trade-off decisions on the level of support service needed for operations.[15] It establishes the processes and procedures to track the resources used or consumed to satisfy the BAAF requirements.

LCM can best be described by the management of the changes due to warfighter needs when compared to the present fighter system. If the warfighter needs are to be met and the present system does not fulfill the need, then some type of modification, upgrade, or new aircraft system needs to be put in place.

This is pictorially presented by Figure 3 below.

Within the BAAF, there are 22 F16 fighter aircraft. These aircraft were acquired in two separate purchases. This has required the BDF and BAAF to employ LCM, and monitor TOC. The TOC concept for the BAAF emphasizes two of the major elements: Procurement and Operations and Support (O&S). In the arena of major upgrades, the BAAF must involve itself in the RDT&E of the upgrade as well. For example, should there be a need to upgrade the radar system, it is likely the new radar would require some RDT&E. This cost could, and probably would, be shared by several countries. Therefore, the BDF and the BAAF would be involved in all aspects of the life cycle and its LCM. This involvement includes all aspects of the problems faced by any country, the balancing of the precious assets of the country as well as its needs.

Figure 4 provides a visual representation of those needs.

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[15] Dr. Gansler, Memo, Definition of Total Ownership Cost (TOC), Life Cycle Cost (LCC), and the Responsibilities of Program Managers; 13 November 1998.

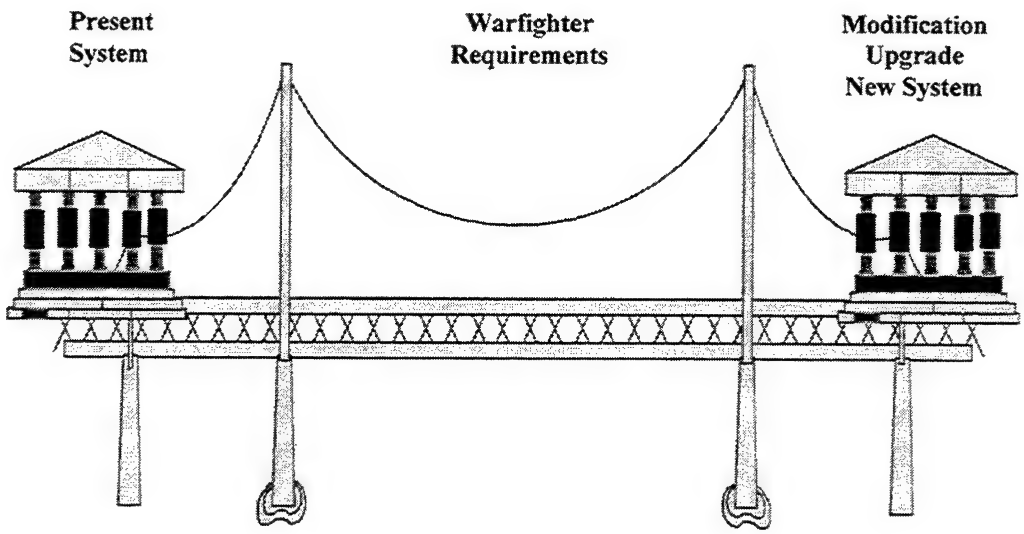

Figure 3. Process Decision for Life Cycle Management (LCM).

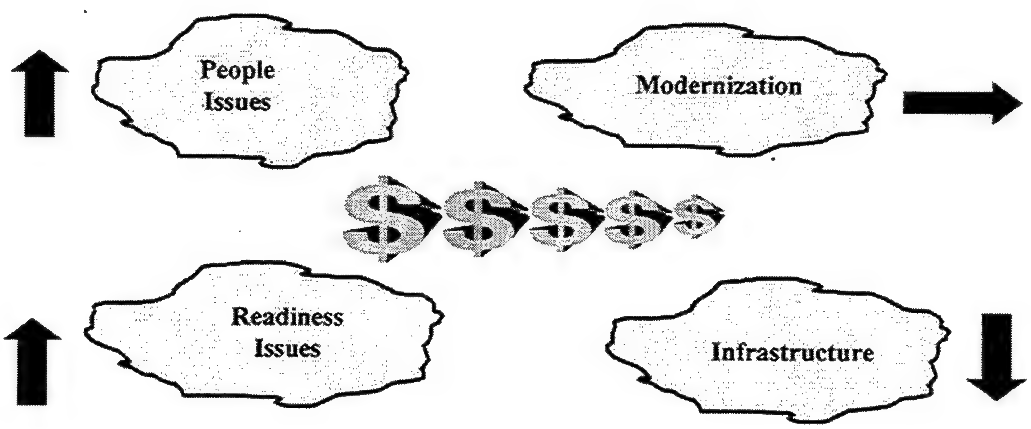

Figure 4. Issues Faced by any MOD.

Failure to perform proper LCM could, and probably would, result in failure(s) to achieve the best possible solution to the needs of the BAAF. It could also result in an O&S cost that would be higher. This higher cost would affect both the MOD and the BAAF by consuming precious currency that could be better used elsewhere.

Utilizing the management techniques defined by LCM, Reduction of the Total Ownership Cost (R-TOC) becomes a continuous effort. This effort is employed by all to maximize LCM in truly reducing the TOC. This continuous effort minimizes the TOC of the weapon system, thereby freeing up funds for other needs. Without an effective LCM, R-TOC would not be possible.[16]

In order to reduce the TOC costs, it is essential to know the make-up of the TOC. There are three distinct elements that comprise TOC. These elements are: Development (sometimes referred to Research, Development Test and Evaluation (RDT&E)), Procurement, and Operations and Support (O&S). Development and Procurement combined are defined as the Program Acquisition. It is also important to understand what sub-elements are included in each of the three major categories.[17]

Figure 5 provides the decomposition of the three major elements into each of the various sub-elements. The Flyaway and additional sub-elements combine to become the Weapon System. It, combined with other additional sub-elements, becomes the Procurement. This continues until all the sub-elements are accounted for and represents the Total Ownership.

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[16] Department of Defense, DoDD 5000.1; The Defense Acquisition System; 23 October 2000, Paragraph 4.4.1 Total System Approach.

[17] Department of Defense Deskbook, 31 January 2001, Open Systems Strategy (dated Aug 2000).

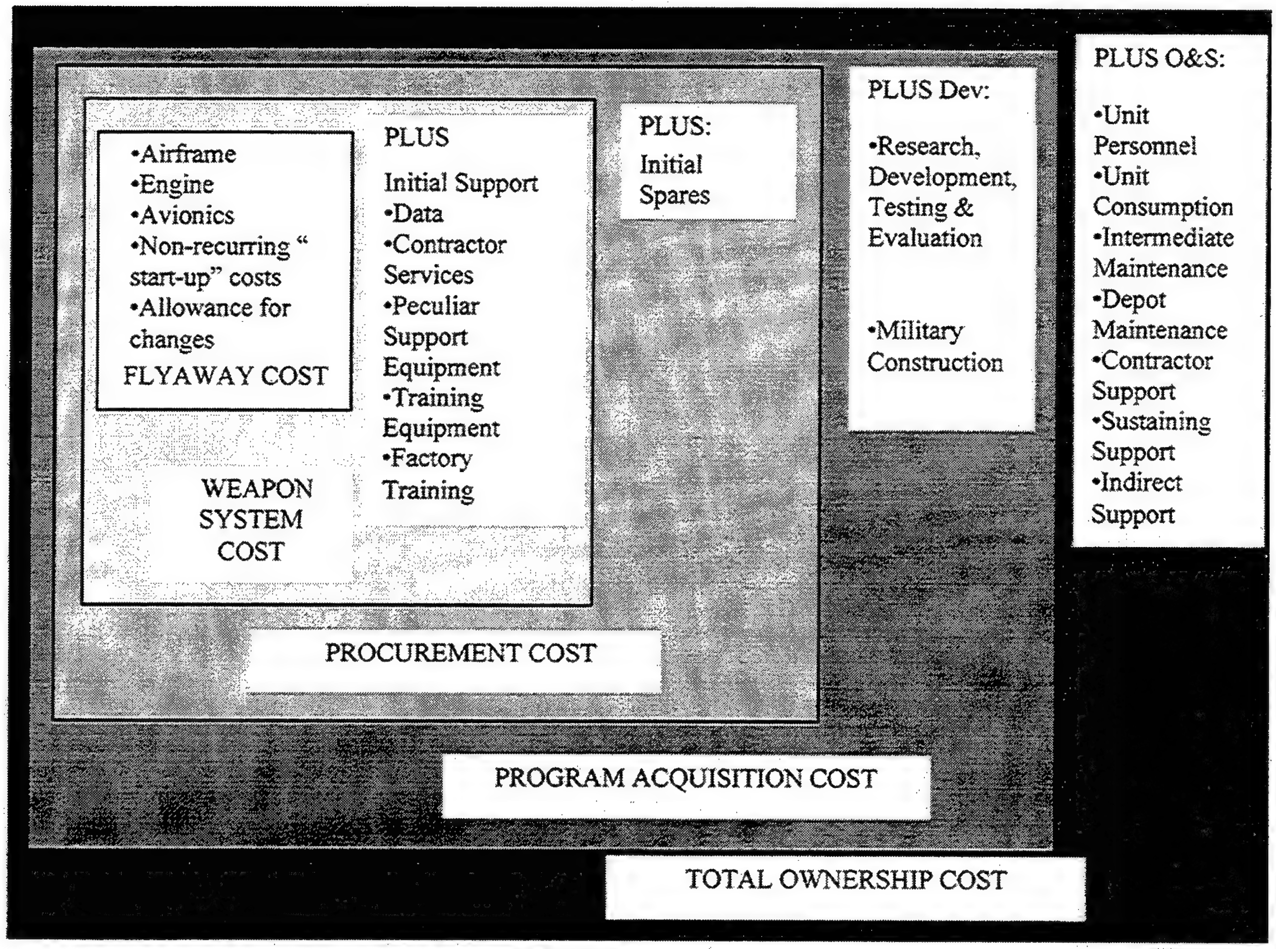

Figure 5. Elements of TOC.

In order to appreciate the value of LCM, it is essential each manager understand the relative values of each of the TOC elements. Relative values are expressed in many different ways, but it is essential to first understand what value is. Basically, value can be expressed as the difference between the benefits (sometimes found out by doing a cost benefit analysis (CBA)) and the costs of the purchase or upgrade.[18] It is expressed as a formula in Figure 6.

[18] AF Manual 65-506; Economic Analysis; 1 July 1995, paragraph 1.2.1.

VALUE = BENEFITS - COSTS

Figure 6. Definition of Value.

Figure 7 provides a visual depiction of the breakdown of the costs associated with TOC.

Total cost visibility prompts the provider and customer to find more efficient methods of accomplishing their respective missions. This makes customer support more efficient and responsive as providers trim production resources and customers cut extraneous/high-value requirements.

D. PROCESS

1. Acquisition

Considering military weapons systems acquisition, the United States (US) Department of Defense (DoD) continually attempts to improve military capability while striving to reduce the high cost of acquiring this capability, producing an efficient acquisition process.

- The defense acquisition system is a single uniform system whereby all equipment, facilities, and services are planned, developed, acquired, maintained, and disposed of within US DoD. The system includes policies and practices, which govern identifying and prioritizing resource requirements, acquisition, contracting, and reporting to the US Congress. A successful weapon system acquisition program is one which places a capable and supported weapon, commodity, etc. in the hands of a user when and where it is needed, and does so within cost and schedule.

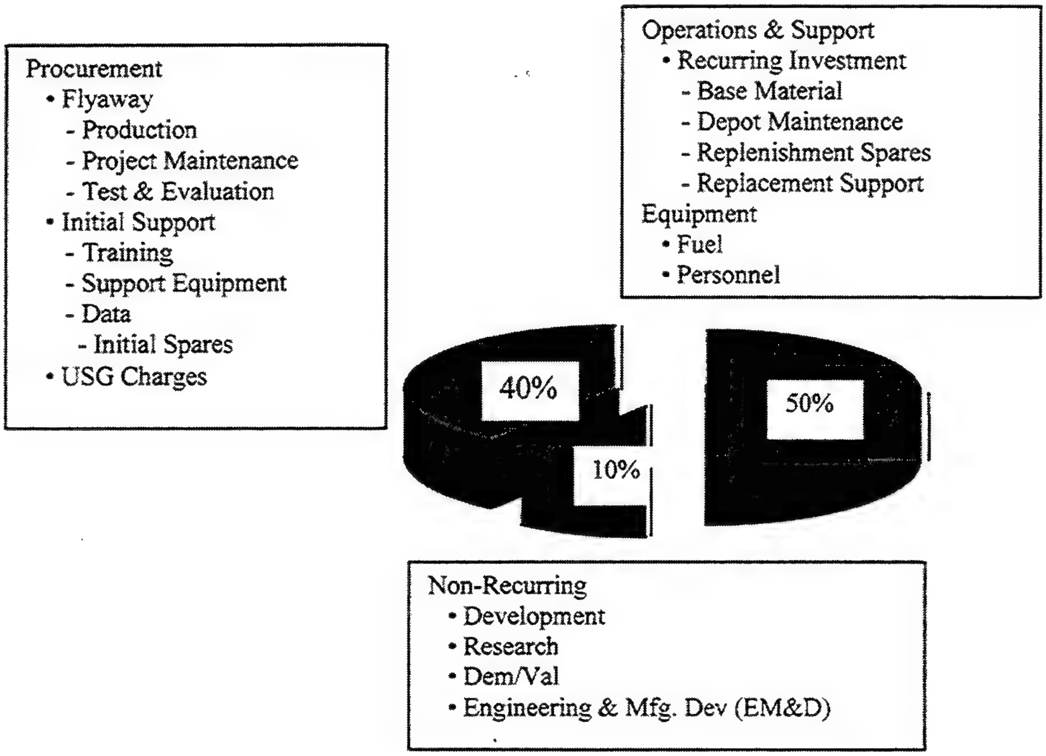

Figure 7. Elements of the TOC.

- The DoD acquisition system includes all facets of acquisition, from new acquisition programs through modification and upgrade of existing systems. The acquisition system's goal is to provide quality products and services at an affordable Total Ownership Cost (TOC) and in a timely manner. The acquisition process begins with the identification of broadly stated mission needs, which cannot be met by non-materiel solutions. The process may continue through one or more of the five acquisition phases.[19]

Figure 8 below provides a visual representation of the elements of the US government involved in the LCM of a weapon system.

[19] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.5.3.

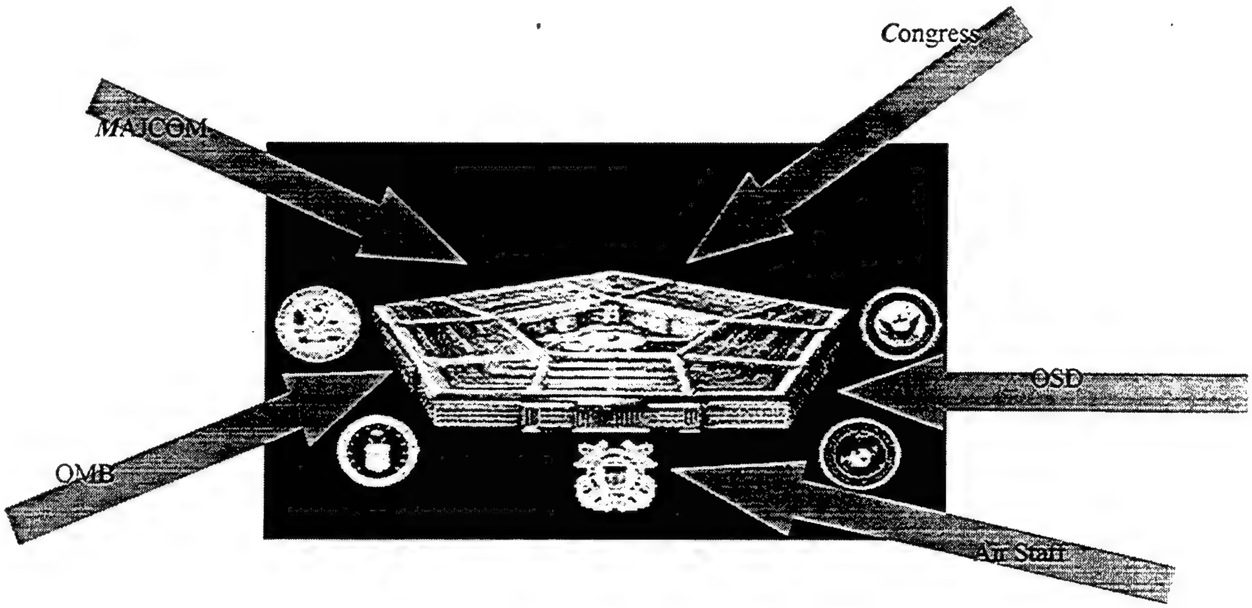

Figure 8. Agencies Involved in LCM.

2. Cost As an Independent Variable (CAIV)

There is a process described as Cost as an Independent Variable (CAIV) utilized within the LCM. This process is used in the negotiation of the requirements necessary for the development process to produce an affordable product as shown by Figure 9 below.

The CAIV process requires engineering and management review to provide the best value for the most affordable price. In order to do this, each trade study must be evaluated in the total scheme of the LCM[20]. The result of this evaluation produces the necessary information for an informed LCM thereby producing what is called the "CAIV Curve" which is shown below in Figure 10.

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[20] Department of Defense Deskbook, 31 January 2001, Cost as an Independent Variable (CAIV), last reviewed Sep 1999.

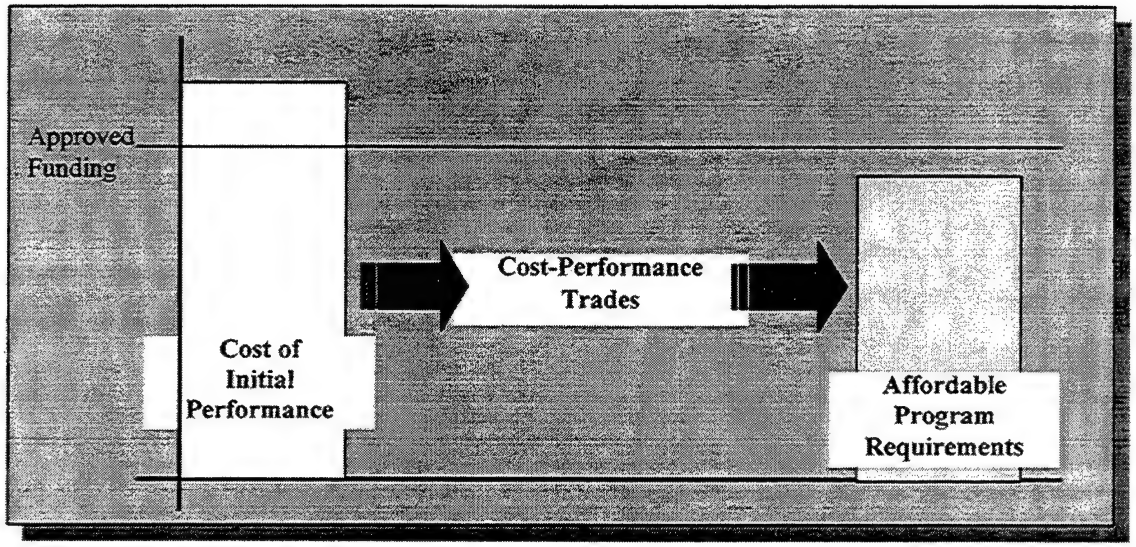

Figure 9. Affordability Issues.

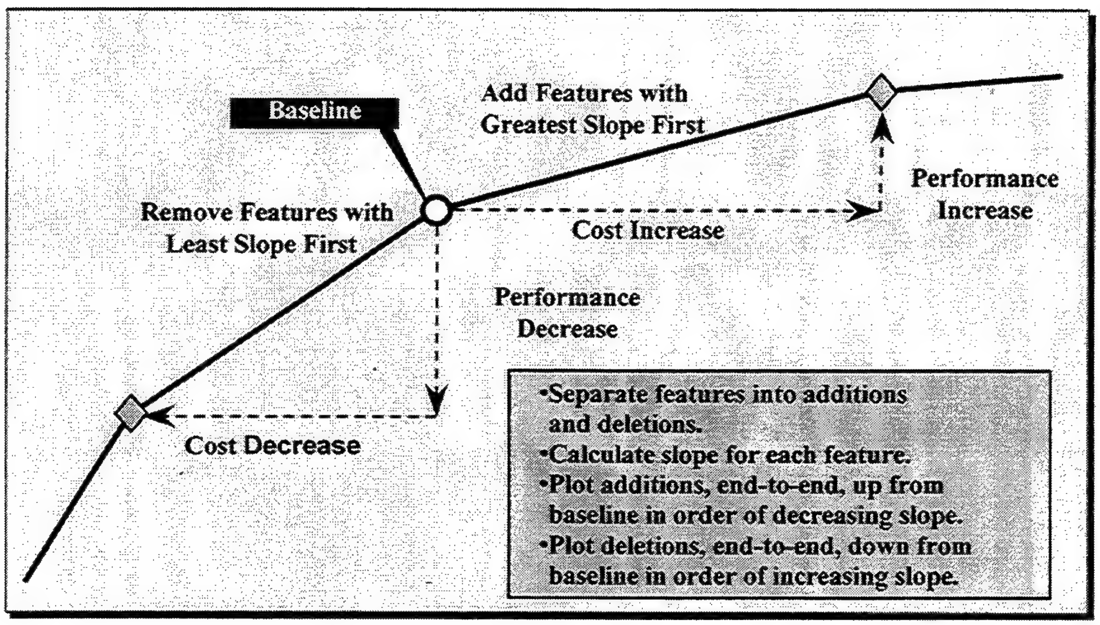

Figure 10. CAIV Curve.

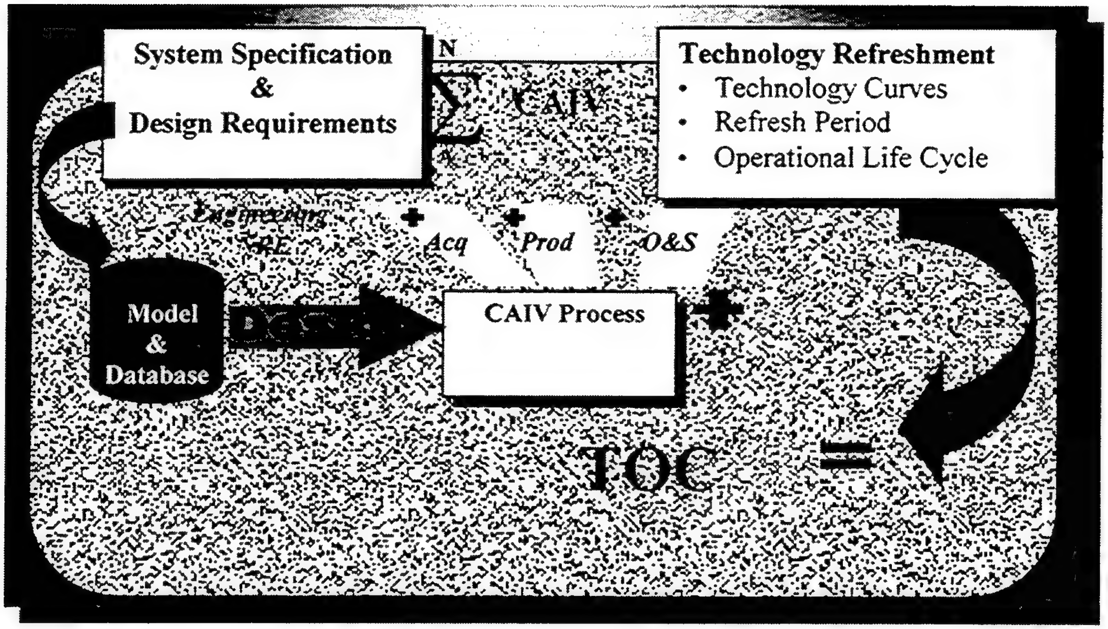

Figure 11. CAIV Interface within the LCM.

Continuing the discussion regarding CAIV, engineering efforts and the LCM combine to produce the best value at the most affordable price. Figure 11 identifies some of the process.

E. MILESTONES AND PHASES IN THE ACQUISITION LIFE CYCLE

1. Background

Defense systems normally take 12-15 years from deficiency identification to system fielding. For purposes of control, an acquisition program is broken down into milestones and phases. A milestone is a decision point scheduled in the Acquisition Strategy. A milestone defines that point in time when a program completes one phase and is ready to move into another phase. The US DoD has five such milestones scheduled at specific points in a program's life cycle. In order to move from one milestone to the next, the program is reviewed and approved by the appropriate level of review within the DoD. The five milestones, designated as Milestone 0 through Milestone IV, are used to manage major defense acquisition programs. Acquisition phases are tailored to meet each

acquisition's needs and to minimize acquisition time and TOC. These five phases are designed to be consistent with the urgency of need and degree of technical risk involved with the program.[21] The acquisition life cycle phases illustrated in Figure 12, beginning with Milestone 0, Concept Studies approval, depicts the:

- system acquisition phases
- nominal length of time required for each phase
- purpose of each related milestones or decision points,
- major documentation required,
- contracting activities associated with each phase

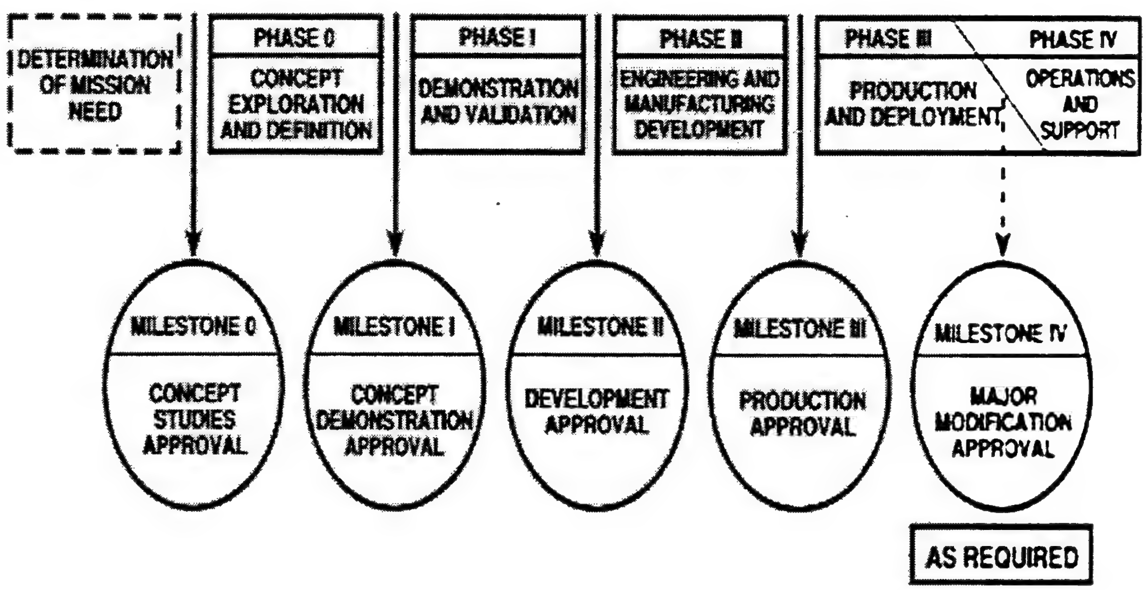

Figure 12. Milestone Decisions Associated with Acquisition Phases.

[21] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001

Figure 13 below provides identification of the risk reduction process used in LCM. This risk is all the risks associated with the program including program risk, schedule risk, cost risk, etc. as established in the risk management process.

2. 2.0 Milestones

- **Milestone 0, Concept Studies Approval.** The decision authority must determine if a validated mission need warrants the initiation of a study of alternative concepts. This milestone marks the initial interface between the requirements generation process and the acquisition management system. A favorable decision authorizes a minimum set of alternative concepts to be studied.[22]

    - Phase 0, Concept Exploration and Definition. The purpose of this phase is to explore materiel alternatives that could satisfy a documented mission need. Cost and operational effectiveness analyses (COEA) are prepared for review at Milestone I. A proposed acquisition strategy is developed for the most promising system concept(s), and initial cost, schedule, and performance objectives are established.

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[22] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.5.3.

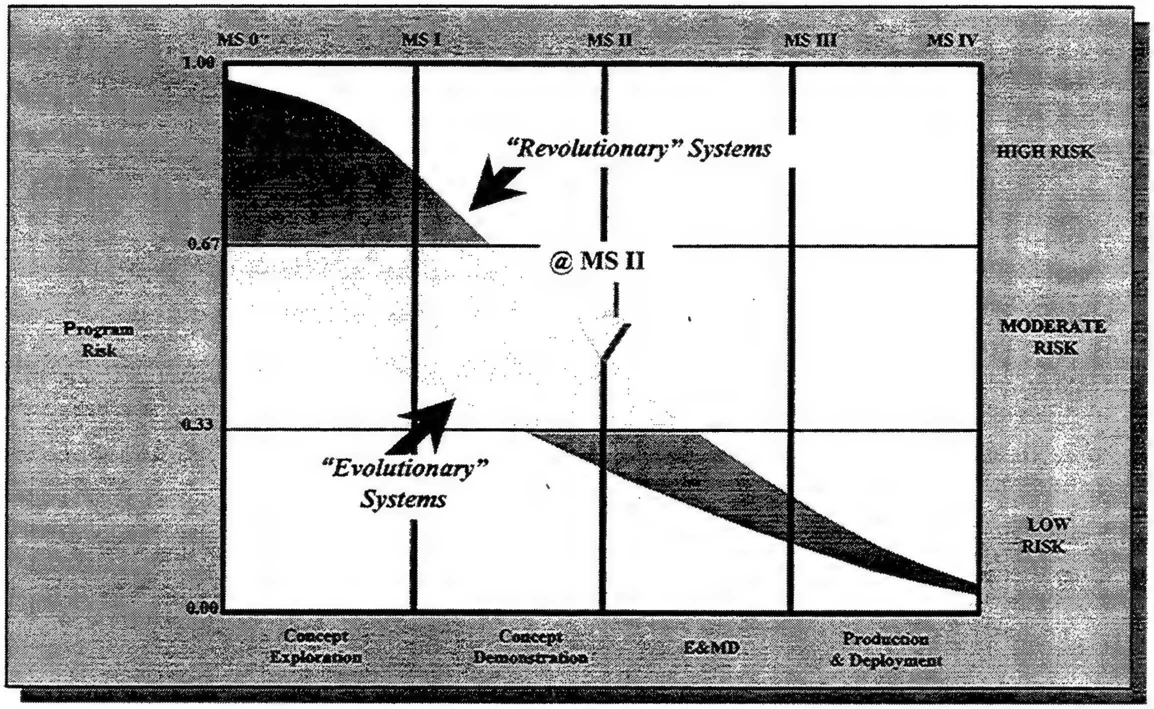

Figure 13. Risk Reduction Process within LCM.

- **Milestone I, Concept Demonstration Approval.** At this milestone, the decision authority assesses the results of Phase 0 and evaluates the affordability of a proposed new program. A favorable decision establishes a new acquisition program, which is authorized to enter Phase I. A "concept baseline" identifying initial cost, schedule, and performance objectives is established.[23]

  - Phase I, Demonstration and Validation. The objective of this phase is to ensure that critical technologies and design approaches are understood and are attainable. Cost, schedule, and performance trade-offs are made within affordability and design-to-cost constraints. A "development baseline" is proposed, and the

[23] DoDD 5000.1, Para C.7 and DoD 5000.2-R, Part 1.5.2, last reviewed Aug 1999.

analyses and information needed to support a Milestone II decision are developed.

- **Milestone II, Development Approval.** The purpose of this review is to determine if the results of Phase I warrant a program's continuation. The decision authority must assess the program's affordability and establish a development baseline containing refined cost, schedule, and performance objectives.[24]

- **Phase II, Engineering and Manufacturing Development.** The objective of this phase is to translate the preferred design approach developed in Phase I into a stable system. Configuration controls are established, and demonstration testing is conducted. The acquisition strategy, system performance requirements, and system cost estimates are refined. Resources are committed commensurate with the control and reduction of risk.

- **Milestone III, Production Approval.** The purpose of this review is to determine whether the results of Phase II warrant continuation of a program. The decision authority must assess the program's affordability, ensure that the system design is stable and producible, and establish a "production baseline" containing refined cost, schedule, and performance objectives.[25]

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[24] DoDD 5000.1, Para D.3.e and DoD 5000.2-R, Part 1.2, last reviewed Aug 1999.

[25] DoDD 5000.1, Para D.3.e and DoD 5000.2-R, Part 1.2, last reviewed Aug 1999.

- Phase III, Production and Deployment. The objective of this phase is to establish a stable, efficient production and support base. The ability of the system to satisfy the validated mission need is assessed. Performance and quality are monitored in follow-on operational support and testing. Needs for major upgrades or modifications requiring Milestone IV approval are identified.

- **Milestone IV, Major Modification Approval.** This review is conducted "as required" to determine if new procurement or major upgrades to a system currently in production are warranted. The need for a new system or major modifications may arise from a change in the threat or a revision in the Defense Planning Guidance (DPG), from a deficiency identified during Phase III testing, or from an opportunity to reduce the TOC. Prior to committing to a major modification, the decision authority may ask for a review of other alternatives, thus reentering the process at Phase 0.[26]

- Phase IV, Operations and Support. This phase overlaps with Phase III, Production and Deployment. The declaration of an initial operational capability or the transfer of management responsibility from the developer to the maintainer marks this phase. Fielded systems are monitored until the time of their disposal in order to assess their capabilities and the effects of aging. Where appropriate, modifications are undertaken to extend service life.

[26] DoDD 5000.4; Cost Analysis Improvement Group (CAIG); (Includes Change 1); November 16, 1994.

As noted earlier, total ownership costs are considered at each decision milestone in the acquisition process. Although the portion of TOC defined as the Operations and Support (O&S) costs are not actually incurred until after a system is deployed, the major decisions that ultimately determine O&S costs are made long before a system is fielded. Beginning with Milestone I, the DoD Cost Advisory Improvement Group (CAIG) must review the program office and independent cost estimates prepared by the sponsoring DoD component to ensure that an independent projection of system costs is available to the relevant Defense Acquisition Board (DAB) committee and to the DAB. Total Ownership cost estimates figure heavily into the evaluation of system alternatives. To compare alternatives over the long term, O&S costs must be estimated and evaluated, particularly in those areas subject to possible change or uncertainty. Since the O&S cost of a weapon system can exceed both the development and production costs, a thorough analysis of O&S costs is required at each acquisition milestone. For each milestone review by the DAB, the CAIG prepares a report summarizing its evaluation of the cost projections submitted by the program office and by an independent cost-estimating team. The CAIG provides any additional estimates that may be required to remedy deficiencies in the cost estimates under review and, if serious problems are found, it may suggest that the DAB committee defer its meeting on the program.

F. DECISIONS AFFECTING AN ACQUISITION

There are three major decision-making support systems affecting acquisition. These support systems are the Requirements Generation System, Acquisition Management System, and the planning, programming, and budgeting system (PPBS).[27]

[27] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.6.1.3.

All three systems must work together to achieve program success, and the financial manager will have responsibilities and reporting requirements for each of these systems. These decision-making support systems are described below and displayed in Figure 14.

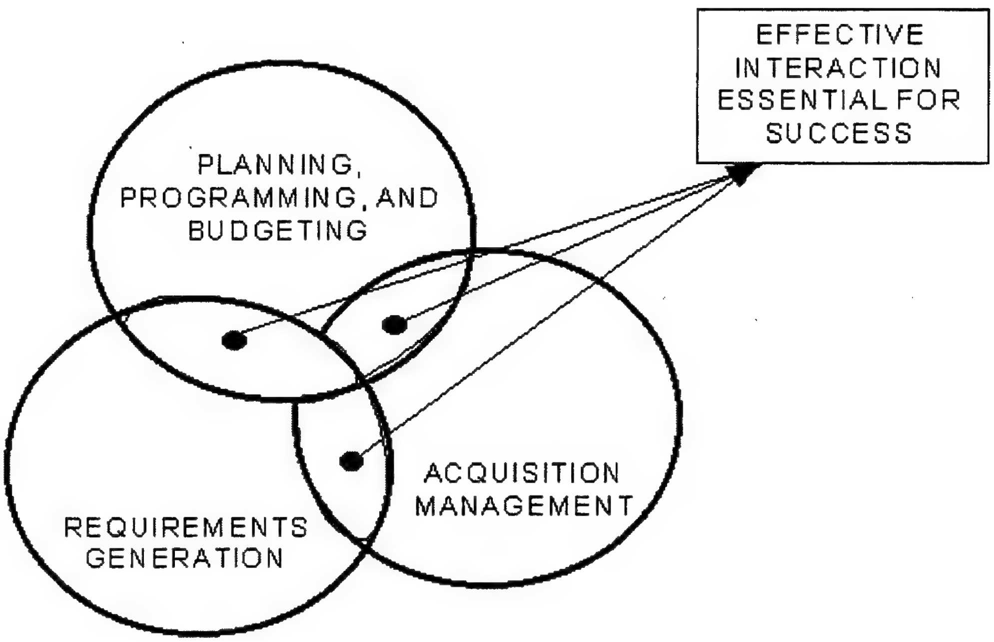

Figure 14. Decision-Making Support Systems.

1. The Requirements Generation System.

Produces information for decision makers on proposed mission needs. These needs are initially expressed in broad operational terms and progressively translated into system-specific performance requirements. The first interaction between the Requirements Generation System and the Acquisition Management System occurs at Milestone I. The Requirements Generation System involves:

- Identifying and processing mission needs resulting from continuing assessments of current and projected capabilities in the context of changing military threats and national defense policy.

- Developing and processing Mission Needs Statements (MNS) which document projected needs in broad operational (not system specific) terms. MNSs are initially forwarded to the Joint Requirements Operational Committee (JROC) for validation and approval. Approved MNSs are then forwarded to the DAB; disapproved MNSs are returned to the originating agency.[28]

2. The Acquisition Management System

Provides a streamlined acquisition management structure and an event-driven acquisition process which links milestone decision points to demonstrated accomplishments. This process provides the basis for making informed trade-off decisions, given affordability constraints and user needs. This is the means for translating user needs into alternative concepts, and finally a stable system design.[29]

3. The Planning Programming and Budgeting System (PPBS)[30]

PPBS provides the basis for making informed affordability assessments and resource allocation decisions on defense acquisition programs. This system is time driven, while the Acquisition Management System is event driven. The PPBS strives to provide operating commanders the best mix of forces and support in view of fiscal constraints. The challenge for the program manager and financial manager is avoiding a mismatch between program requirements and available funding. The PPBS is managed by the Deputy Secretary of Defense with assistance from the Defense Program Review

[28] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.6.1.1.

[29] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.6.1.2.

[30] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.6.1.3.

Board (DPRB). Formal interface between the PPBS and Requirements Generation System occurs every two years when Military Departments (MILDEPs) and defense agencies submit their Program Objective Memoranda (POM) to the Office of the Secretary of Defense (OSD). This system is comprised of three phases -- planning, programming, and budgeting.

- The Planning Phase results in the development of a broad long-range investment plan for each DoD Component (with programming and budgeting responsibilities) in addition to the Defense Planning Guidance (outlines broad policy objectives and military strategy).

- The Programming Phase results in the development of a six-year defense program, called the fiscal year defense program (FYDP)[31], for each DoD Component and DoD as a whole. The FYDP links national policies, strategy, and objectives to specific forces and major programs, including acquisition programs. It is based on the Defense Planning Guidance and on updated out year fiscal projections. The FYDP proposals for each DoD component with programming responsibilities are documented in the POM submitted in April of every other (even numbered) calendar year. The Deputy Secretary of Defense determines which actions are to be taken on each issue. These decisions are recorded and issued to each DoD Component in a Program Decision Memorandum (PDM). This PDM provides the basis for the financial plans developed during the budgeting phase.

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[31] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.7.3.2.1.3.

- The Budgeting Phase results in the development of the Secretary of Defense's recommendations to the President for the administration's biennial budget request for DoD. DoD budget proposals are forwarded to the DoD Comptroller in the Budget Estimate Submission (BES) submitted in September of every other calendar year.[32] Budget hearings are conducted by representatives of the DoD Comptroller and focus on the execution status of specific programs, including programs reviewed by the DAB. Results of these hearings are documented in Program Budget Decisions. These documents provide alternatives to the budget estimates submitted by the DoD Components. Budget wrap-up meetings, held in December by the SECDEF and the DEPSECDEF, are used to raise and resolve major issues before the budget request is finalized. SECDEF decisions are then documented in DoD's biennial budget request, which is submitted to the Office of Management and Budget (OMB) for inclusion in the President's budget request that is submitted to Congress in January.

G. SUMMARY

Life Cycle Management (LCM) begins when there is a stated need that creates an approved requirement and ends when a weapon system is removed from service. This is commonly called "cradle to grave". Management is essential throughout the weapon system's entire life cycle. LCM begins when there is an approved requirement. It continues through the design phase, development phase, procurement phase, and the operations and support phase. During this time, the management of the cost of all aspects

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[32] DoDI 5000.2; Operation of the Defense Acquisition System; (Including Change 1); 4 January 2001, paragraph 4.7.3.2.1.3.

of the weapon system results in the most affordable Total Ownership Cost (TOC) possible. Failure to continuously manage the weapon system effectively will undoubtedly result in higher costs, unnecessary requirements, longer development cycle, and unfulfilled requirements. All of which result in a weapon system unacceptable to the country, the BDF, and the BAAF.

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IV. TOTAL OWNERSHIP COST

A. DEFINITION

Total Ownership Cost (TOC) has been discussed briefly in earlier chapters in general terms. A more complete definition of TOC is:

> The sum of financial resources to organize, equip, sustain, and operate military forces to meet national goals, policies, and standards of readiness, environmental compliance, safety, and quality of life concerns. The TOC for Defense systems consists of the costs to research, develop, acquire, own, operate, and dispose of weapon and support systems. It includes direct costs and indirect costs attributable to the systems and infrastructure costs not directly attributable to the system. Product support mainly concerns the portion of TOC that occurs after the system is deployed (the sustainment and disposal phase of a system's life cycle).[33]

B. OBJECTIVES

The Bahrain Defense Force (BDF) must pay strict attention to any major acquisition. This is necessary to not only maintain the budget but to insure the country's defensive capability. The BDF needs to evaluate the stated requirements expressed by the defense agencies, such as the Bahraini Amiri Air Force (BAAF), but also to assure that the solution is affordable. As with any country's defense departments, there are conflicting requirements, and needs greater than budgets can accommodate. This is why the BDF must insure that Life Cycle Management (LCM) is well planned and strongly implemented. The Total Ownership Cost (TOC) for the weapon system must be known and managed throughout its life cycle. In the case of the BAAF F16 fighter aircraft, the TOC for planning purposes represents those costs that are not sunk. Many modifications, support procedures, warranties, guarantees, etc. involved with the support to the F16 organization within the BAAF must still be managed using LCM techniques.

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[33] Department of Defense (DoD) 5000.2, paragraph E2.1.20.

Modifications, upgrades, and the support structure for the F16 organization will continue for some time and require aggressive management and support by all echelons.

The objectives of TOC are to:

- Support Life Cycle Management (LCM): Without insight into the TOC for the F16 organization, there cannot be any Reduction of Total Ownership Cost (RTOC). This could also cause unnecessary O&S costs incurred by aging aircraft that has not been managed properly due to lack of information and management attention.

- Provide budgetary analyses: Coupled with the LCM of the F16 fleet and its organizational structure, is the requirement to pay the support costs. This would include acquisition of modifications and upgrades that may, or may not, cause a RTOC. Sometimes, operational requirements dictate an increase in O&S costs, which must be managed aggressively to minimize that increase.

- Maintain visibility into any acquisition or modification of a weapon system. Through technical representatives from the various suppliers and exchanges of information between them, what is being developed for modifications and upgrades can be known. Through this knowledge, the BDF and the BAAF can better determine if this modification/upgrade is necessary for Bahrain.

- Support internal cost controls. The BDF has a responsibility to maintain expenditures within its budget. In order to accomplish this, it must have a

clear understanding of the effects of the TOC for the F16 organization. It is incumbent upon the entire F16 structure to know and manage TOC with constant efforts to reduce that cost (RTOC).

- Insure affordability
  - The affordability determination is made while addressing cost during the requirements definition process, beginning with the acquisition cost but using TOC where available and validated.[34] Approval of the TOC estimate is reviewed during each budget cycle with updates in between. Should the TOC exceed the budgeted amount for the F16 organization, immediate actions must be taken to eliminate the budget overrun. These actions could be in the form of reduced flying hours or more drastic measures such as not flying some percentage of the aircraft. This is a decision that must be made by the decision-makers using LCM. TOC must support the LCM and therefore maintain the F16's affordability.
  - Many times there are alternatives identified in the requirements definition phase of any acquisition. Analysis of Alternatives (AOA) is part of the Cost as an Independent Variable (CAIV) process.[35] Cost must be viewed as an independent variable, and the BDF and the BAAF need to plan programs based on realistic projections of funding likely to be available in future years. To the

[34] Department of Defense (DoD) 5000.2, paragraph 4.7.3.2.2.4.

[35] Department of Defense (DoD) 5000.3-R3, paragraph 4.2. -- Analysis of Alternatives (AoA).

greatest extent possible, they should identify the TOC, and, at a minimum, the major drivers of TOC.[36] It is essential to the TOC process that each alternative be examined, includings all elements of the TOC from design to disposal. This includes the associated Line Replaceable Units (LRU). The analysis should consider the benefits and detriments, of accelerated and delayed introduction of military capabilities, including the effect on TOC.

- As part of the acquisition strategy, program managers should develop and document a support strategy for life-cycle sustainment and continuous improvement of product affordability, reliability, and supportability, while sustaining readiness. This effort should ensure that system support and life-cycle affordability considerations are addressed and documented as an integral part of the program's overall acquisition strategy. The support strategy should define the supportability planning, analyses, and trade-offs conducted to determine the optimum support concept for a materiel system, and strategies for continuous affordability improvement throughout the product life cycle. The support strategy should continue to evolve toward greater detail as the program matures. It contains sufficient detail to define how the program will address the support and fielding requirements that meet readiness and performance objectives, lower TOC, reduce risks, and avoid harm to the environment and human health.[37]

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[36] Department of Defense (DoDD) 5000.1, paragraph 4.5.2. -- Cost and Affordability.

[37] Department of Defense (DoD) 5000.2-R1, paragraph 2.8. -- Support Strategy.

C. ELEMENTS OF TOC

Figure 5 above identified the elements of TOC in definitional terms only. In order to fully understand the impact of TOC, a more complete understanding of each element of TOC must be insured. These elements are acquisition and operations and support (O&S).

- The program acquisition is composed of two major elements, (1). Research and development (R&D) and (2) Procurement.

    - Both the BDF and the BAAF in any acquisition determination must consider R&D. This is true in the total weapon system acquisition as well as in any new modification to the aircraft. Even though the F-16 fighter aircraft has already been purchased by the BAAF and has been in the BAAF inventory for a period of years, modifications are continually being developed and installed in the worldwide fleet of F16s. These modifications require some form of R&D. The R&D of a new fighter or a modification could cost 10-15% of the TOC. The BDF and the BAAF must monitor these modifications and determine if they fit the profile and requirements of the BDF, the BAAF, and are affordable. For example, suppose a new radar system is under development. That development cost and its associated procurement cost is normally quite high for the first few radar systems procured. The BDF and the BAAF must determine if it is a pressing current requirement and affordable, or should they wait and procure the item when it is less costly?

- Procurement of newer F16 aircraft or modifications to the existing fleet causes focused TOC analyses. Not only is there the concern regarding R&D cost, but also the cost of the procurement of all of the items to be procured. Included in this affordability analysis are the costs of any infrastructure changes that might be necessary, the initial spares needed, training necessary for operators and maintainers, etc. Procurement could easily account for 35-40% of the TOC. These cost elements are normally expressed as:

  - Flyaway cost. Figure 5 above provides a listing of the elements considered in the flyaway cost of an F16. This is a sunk cost for the existing F16 fleet in the BAAF, but would be a factor in any further acquisitions.

  - Recurring Costs. Recurring costs are repetitive elements of development and investment costs that may vary with the quantity being produced during any program phase. For example, during the development phase repetitive production-like costs incurred when producing prototype and test units are considered recurring costs. Recurring costs include the following: engineering, required for redesign, modifications, reliability, maintainability, and associated evaluation and liaison; complete reporting elements produced either for test or for operational use; tool maintenance, modification, rework, and replacement; training all Service

personnel to operate and maintain equipment; and reproduction and updating of technical data and manuals.

- Nonrecurring Costs. Nonrecurring costs are those elements of development and investment costs that generally occur only once in the life cycle of a system. Such costs are often found in engineering, system tests, tooling, and pre-production activities, and also include basic design and development through the first release of engineering drawings and data, all system and subsystem test activities, except end item acceptance testing, configuration audits, qualification testing, technical publications through initial release, basic tool and production planning through initial release, all basic tooling, engineering models, partially built units for development or test purposes only, units not built to operational or tactical configuration, and specialized work force training.

- Initial Spares. Initial spares are relative to the amount of flying the F16 would accomplish during its initial BAAF service. This cost is also sunk.

- Initial Support. The elements included in initial support are again described in Figure 5 above. This cost is also sunk for the existing F16 fleet.

- The O&S cost includes all costs associated with the operations, maintenance, and disposal of the F16 aircraft, or the modifications to

aircraft or support equipment. O&S costs can be as much as 45-55% of the TOC. These cost elements are broken down into:[38]

- Mission Personnel. This cost is the flight crews and the squadron/wing personnel involved in the support of the unit mission.

- Unit-level consumption. This is the fuel and other Petroleum, Oil, and Lubricants (POL) associated with the aircraft and its support equipment.

- Intermediate Maintenance (External to the unit). This cost is the maintenance and support costs above the unit level but not at the depot.

- Depot Maintenance. This includes all costs associated with depot support to the BAAF.

- Contractor Support. This includes the cost of contractor labor, materials, and overhead incurred in providing all or part of the logistics support required by the F16 weapon system, its subsystems, or associated support equipment.

- Sustaining Support. This includes the cost of replacement support equipment, modification kits, sustaining engineering, software maintenance support, and simulator operations provided for the F16 weapon system.

[38] Department of Defense (DoD) CAIG Aircraft O&S Cost Element Structure.

- Indirect Support. Indirect support includes the costs of personnel support for specialty training, permanent changes of station, and medical care. Indirect support also includes the costs of relevant host installation services, such as base operating support and real property maintenance.

The combination of acquisition and O&S costs (which would include the disposal cost) represents the TOC for the F16 weapon system.

D. METHODOLOGY

Knowing what the TOC for the F16 weapon system is only the start of the LCM process. The methods used to calculate the various elements of TOC must be known and understood. Accounting for all the costs associated with the complete F16 weapon system can be a complex process, as shown in Figure 15 below, and require a tremendous amount of data.

The TOC development process is depicted in Figure 16 below. It portrays the development of the acquisition values in the upper left that results in the upper right in the Life Cycle Cost (LCC). LCC is equivalent to the TOC within the BAAF. Simultaneously, the support concept for the system/LRU is determined by the tan color. These costs culminate in the values on the right side indicating the O&S costs. The summation of the acquisition (Development and Procurement) and the O&S costs result in the TOC. The items circled in red are those items that normally occupy the trade space for trade studies associated with RTOC and affordability. Trades are very much a part of the TOC, especially for the BAAF F16 fleet. These are the actions discussed earlier where the BDF and the BAAF have to maintain liaison with the manufacturers, vendors, and the US government relative to the upcoming modifications and upgrades that drive

the trade study analyses. The results of those analyses must be known and monitored by all levels of the F16 organization and the BDF. The results of purchasing those modifications/upgrades could well cause a reduction of the TOC (RTOC).

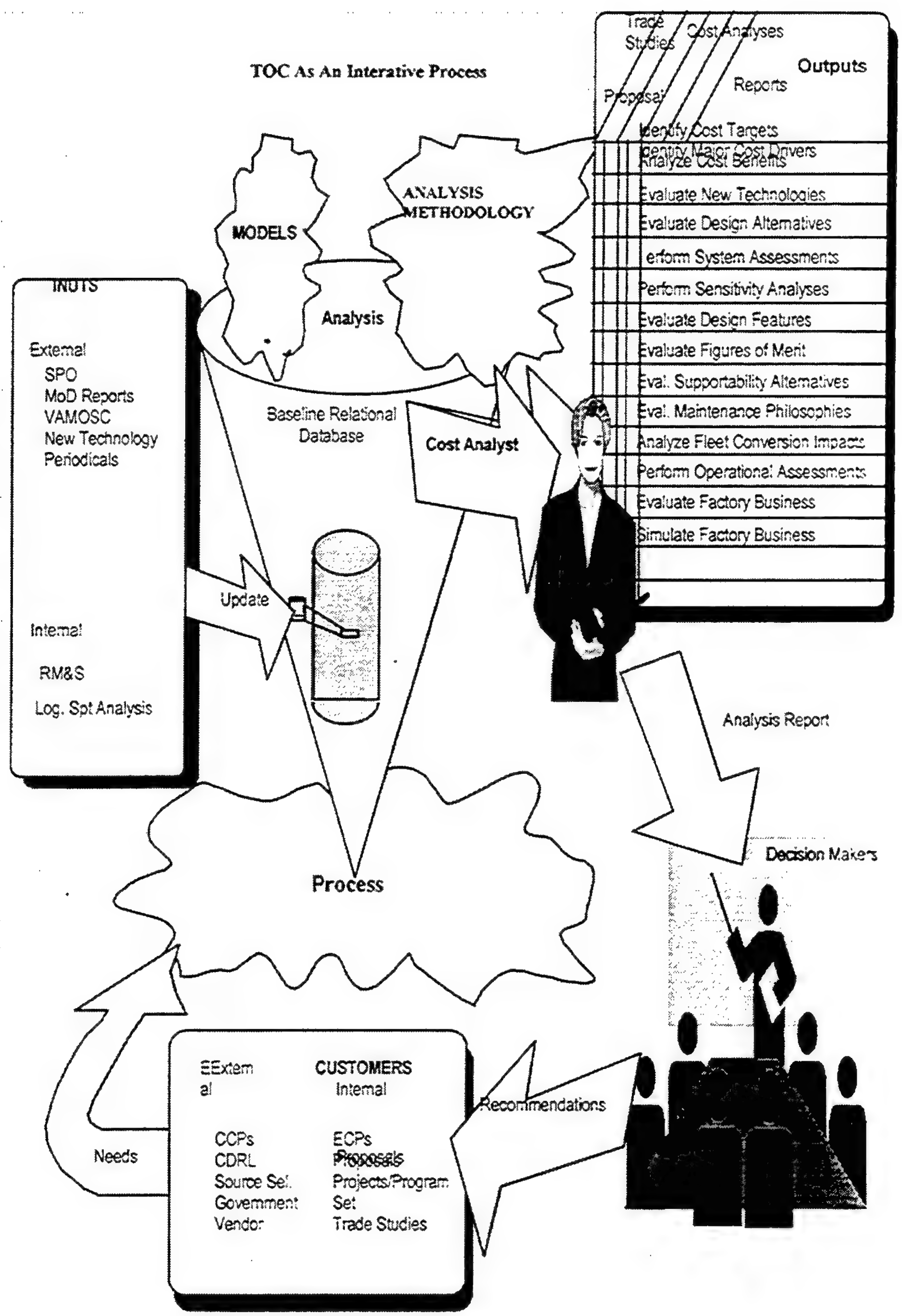

Figure 15. Methodology for TOC.

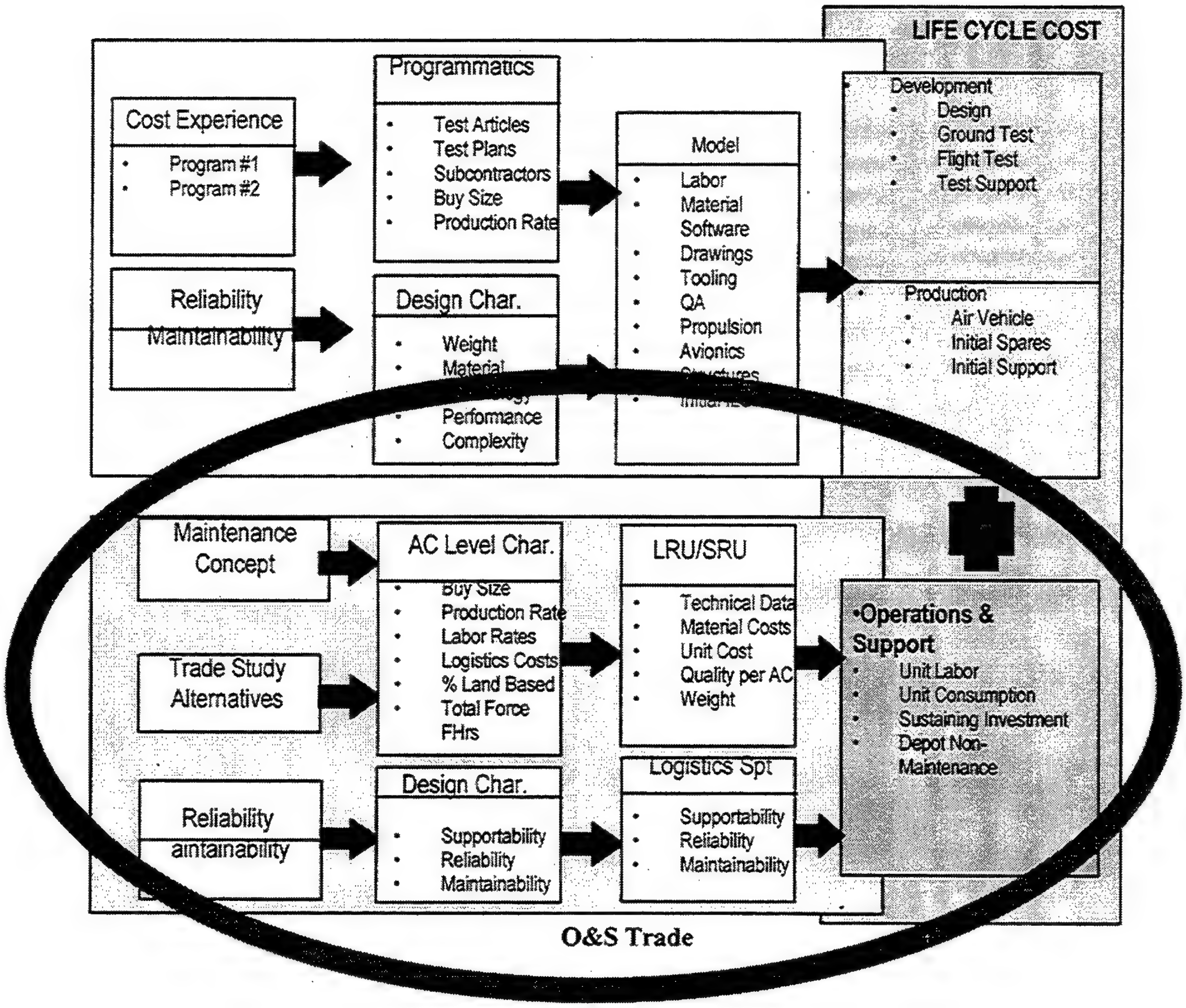

Figure 16. TOC Process with Trade Study Space Highlighted.

This methodology should be broken down into requirements definition, data collection, data analyses, cost models selection, cost model input requirements, cost model outputs, cost analyses, reports to decision makers, as part of an iterative process to find the most affordable product strategy can be derived.

Requirement definition is conducted by the BAAF and the BDF to identify the needs of the BAAF. This can, and usually does, relate to some problem relative to the BDF. It results from the evaluation of the defense needs of Bahrain and the shortfalls in present systems.

Once there is a determined need for some procurement or modification, then data collection must occur. The data collection plan must include all information/data required to determine the TOC of the system. Coupled with this could be the requirement for the Reduction of TOC (RTOC). This is normally brought about through some modification or series of modifications to the F16 fleet. By finding better ways/methods of producing a given Line Replaceable Unit (LRU) for the F16 weapon system, the TOC can be reduced. This reduction normally occurs through different materials or increasing the reliability and maintainability of the LRU. Figure 17 below attempts to portray the affects of the efforts to reduce the TOC for an LRU.

TOTAL OWNERSHIP COST

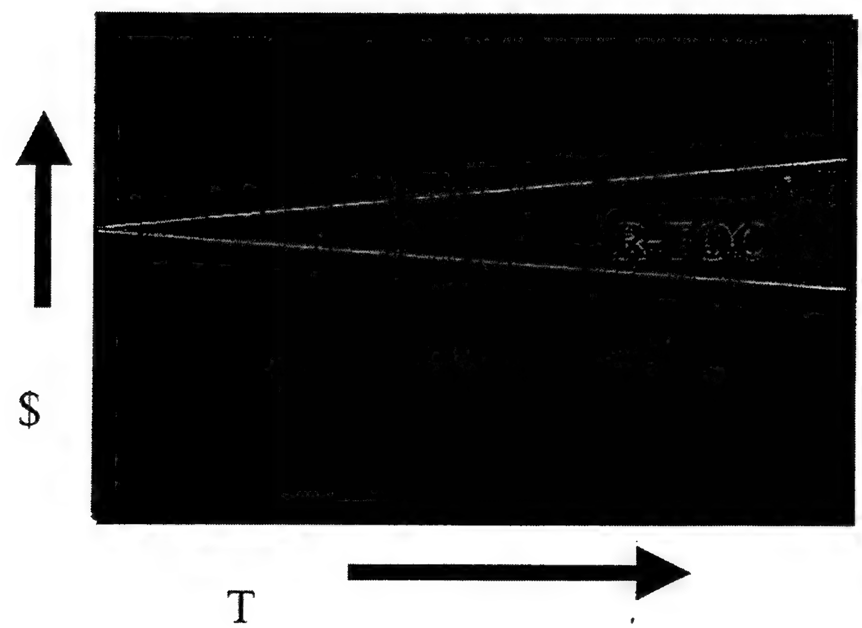

Figure 17. Effects of RTOC.

To further describe the RTOC, Figure 18 below describes a process developed by the United States Air Force (USAF) for one of its weapon systems (F117). The Bahrain

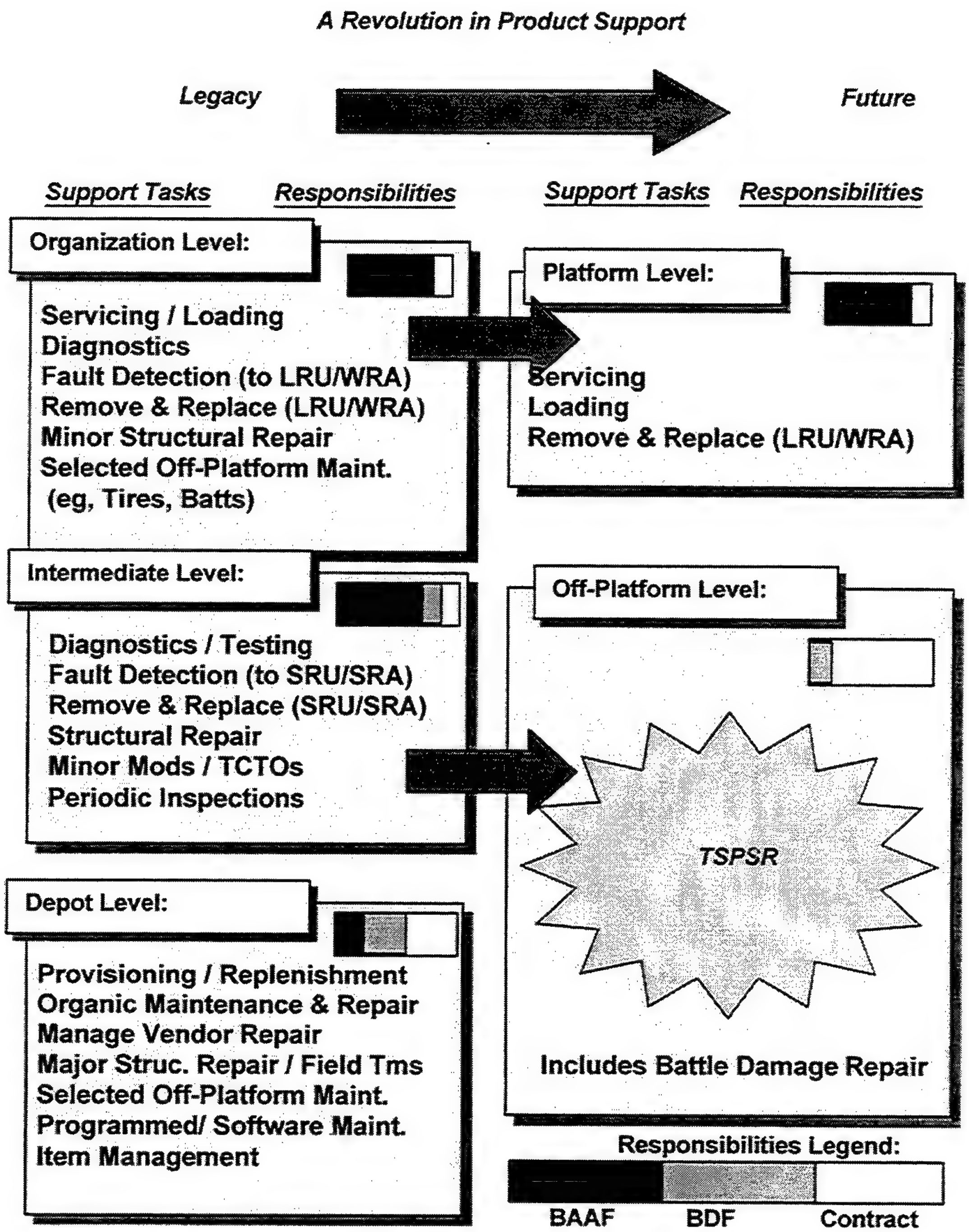

Figure 18. Total System Performance Specification (TSPR) for RTOC.

BDF and the BAAF should seriously consider employ this process. It is referred to as Total System Performance Specifications (TSPR). It is the method whereby the contractor provides the entire support portion of the O&S excluding the indirect costs.

Other Foreign Military Sales (FMS) countries are also using this methodology. It is the equivalent of outsourcing the support to the contractor. The figure below describes the process of evolution that is necessary for the RTOC of the support portion of the TOC. This evolution begins with the legacy system of support presently used by the BAAF and culminates in the support system being totally the responsibility of the contractor. This methodology has produced millions of US dollars in saving for the USAF weapon system. The quantity of aircraft supported and the support structure is quite similar to that of Bahrain.

E. COST MODELS

For any type of TOC analyses, there is a need for cost models. These models make up the "tool box" used by the cost analysts to estimate costs to any level of fidelity needed by the decision-makers. They provide Rough Order of Magnitude (ROM) estimates down through, and including, very detailed analyses of the TOC.

There are several types of cost models just as there are various tools in the mechanics tool box. Each type of tool serves some purpose. Which tool(s) to use is a decision the cost analyst must make based on what the requirement for the cost analysis is and how much data is available. Data for the F16 fighter aircraft is quite well known, and includes the data generated within the BAAF since its F-16 acquisitions. A couple of types of cost models are:

- Parametric models. Used more frequently when data availability is limited. The have a much stronger reliance on the development of Cost Estimating Relationships (CER) that is inserted into the model.

- Grassroots models. Used when plenty of data is available.

- Uses
    - Rough Order of Magnitude (ROM) estimates.
    - Budgetary
    - Life Cycle Management
- There are a host of cost models available in the international market place. It is beneficial to use models also used by the US government and the F16 contractors in order to insure collection and use of data, algorithms, and CERs are reasonable.
- TOC Models. These models are used to determine the F16 weapons system costs at the system level through, in some cases, the third level of indenture of the Cost Estimating Structure (CES). This provides decision makers the ability to determine the costs for acquisition or trade studies necessary. Some of the cost models in this category are:
    - Parametric Review of Information for Costing & Evaluating (PRICE)
    - System Evaluation and Estimation of Resources (SEER)
    - Fighter Life Cycle Cost Model (FLCCM)
    - Cost Analysis Strategy Assessment (CASA)
- O&S Models. These models are used to provide ROM level of fidelity through five levels of indenture for CES for the cost analyses of O&S. They can be used for the computation of O&S costs at the F16 weapon

system level down through the LRU/SRU level. Some of these type of models are:

- System Level Operations & Logistics Support (SOLS)
- Logistics & Operations Support (LOGOS)
- Cost Oriented Resource Estimating Model (CORE)
- Recurring Investment Factors (RIF)
- Fuel Consumption (FC)

- Software Models. These models are used to determine the cost of software development and maintenance. The cost analyst for the F16 fighter aircraft must modify the inputs, therefore, the outputs for the computation of software maintenance. This must be done since the models are built for business type computations and not for fighter aircraft operations. Some of these models are:
    - Revised COCOMO (REVIC).
    - Constructive Cost Model (COCOMO).

F. TYPICAL OUTPUT SUMMARY FOR TOC

There are many ways of portraying TOC for the F16 or its LRUs. Table 1 below presents one method of providing information to the decision-makers. The level of presentation is dependent on the level of management. For example, a peer review would require presentation of the complete set of inputs and outputs with discussions regarding the ground rules and assumptions included. A review for the manager/squadron commander would require less detail and more summary. A review at the program

manager/wing commander level would require still more overview of information and less detail. The details would be provided as back-up information, if requested. A briefing to the Bahrain BDF would be at the highest level and the details would be attached.

Chapter V will present a generic cost analysis of F16 fleet TOC. It will present the TOC of the F16 fleet in a manner that the BDF and the BAAF can adapt for its LCM management processes.

1.0	Development	10%				$1,774,691
	Aircraft Design Analysis & Tooling		32%			$567,901
	- Procurement			13.0%		$73,827
	- Engineering Design & Analysis			12.0%		$68,148
	- Tooling			7.0%		$39,753
	Test and Test Hardware		39%			$692,130
	- Ground Test			9%		$62,292
	- Flight Test			10.0%		$69,213
	- Test Hardare			20.0%		$138,426
	Systems Project Mgmt & Data		11%			$195,216
	Support Equipment & Management		18%			$319,444
2.0	Procurement	40%			$28,395 K	7,098,765
	Flyaway		81%		$23,000 K	$5,750,000
	- Recurring Production			90.0%	$20,700 K	$5,175,000
	* Sustaining Engineering					
	* Sustaining Tooling					
	* Manufacturing					
	* Quality Assurance					
	* Logistics					
	- Nonrecurring Production			10.0%	$2,300 K	$575,000
	* GFE					
	* ECPs					
	* Systems Test & Evaluation (ST&E)					
	* Initial Operating Capability (IOC) – Tooling, Facil.					
	Initial Support		19%		$5,395 K	$1,348,765
	- Training					
	- Support Equipment					
	- Data					
	- Initial Spares					
3.0	Operations and Support	50%				$8,873,457
	Recurring Investment		59%			$5,235,340
	- Replenishment Spares			14.0%		$732,948
	- Base Maintenance Support			8.0%		$418,827
	- Depot Maintenance			18.0%		$924,361
	- Aircraft Modifications			12.0%		$628,241
	- Replacement Common Support Equipment			7.0%		$366,474
	Fuel		22%			$1,952,160
	- Peacetime					
	- Training					
	- Maintenance					
	Personnel		19%			$1685,957
	- Aircrews			2.4%		$40,463
	- Maintenance			11.9%		$200,629
	* Unsched Maintenance				3.80%	$7,624
	* General & Support				1.50%	$3,009
	* Weapons, etc.				3.30%	$6,621
	* Support Equipment				2.50%	$5,016
	- Support			4.7%		$79,240

Table 1. A Type of TOC Summary Report.

V. BAAF F-16 TOTAL OWNERSHIP COST

A. GROUND RULES AND ASSUMPTIONS

Now that we have discussed in detail the definitions and use of Life Cycle Management (LCM) and Total Ownership Cost (TOC), it is time we discuss specifically the F16 fighter aircraft fleet in the BAAF. This chapter is dedicated to discussion of F-16 costs. It must be recognized that some of the information presented in this chapter will be generic in nature due to the sensitivity and classification of some of the relevant information. Use of certain BAAF- specific information could possibly disclose classified operational procedures.

As with any cost analysis, the first step in estimating TOC is determination of the ground rules and assumptions. These set the stage and insure the cost analyst is synchronized with the BDF and the BAAF. Ground rules and assumptions change since the reasons for, and the depth of, any given analysis play an important role. Ground rules are those hard and fast points normally provided to the analyst.

At the same time assumptions are determined by analyst and program management judgments. These are identified to tell reviewers and decision makers what was assumed in order to complete the cost analyses.

1. Ground Rules

- Number of Primary Aircraft Authorized(PAA): 22
- Number of squadrons: 2
- Number of wings: 1
- Flight Hours FH Per Aircraft (AC) Per Year: 180 FH

• Crew Ratio (# crew per # aircraft):	1
• Pilots per Crew (# total F16 pilots per AC)	1
• Non pilots per crew (navigators, etc.)	0
• Enlisted per crew	0
• Number of pilots in the squadron	22
• Pilot Turnover Rate:	4.81%
• Officer Turnover Rate:	6.95%
• Enlisted Turnover Rate:	10.25%
• Operational Service Life:	8000 Flight Hours (FH)
• # F16 Aircraft delivered in Jun 1980:	10
• # F16 Aircraft delivered in Jun 1990:	12
• Levels of Maintenance:	3
• Year Dollars	Current

2. Assumptions

• Fuel cost per gallon:	$1.00 US
• Organic (US) depot maintenance	100%
• Number of bases:	1
• Support Equipment (SE) Replacement	Only as required
• Base Level Labor Rate:	$32.30

- Organic Depot Labor Rate: $90.50
- Mission Mix Normal

B. PROCUREMENT

Research, Development, Test and Evaluation (RDT&E) is considered to be the development portion of the acquisition cost. It begins at Milestone 0 and continues to the production. This is considered a sunk cost for the acquisition and TOC of the weapon system (F16). RDT&E becomes applicable in the development of modifications and upgrades to the weapon system.

The Bahrain Defense Force (BDF) and the BAAF were involved in the procurement of the F16 fighter aircraft fleet. This occurred in two segments. The first segment was the procurement of 10 F16 aircraft in 1980. The second procurement of 12 F16 fighter aircraft occurred in 1990. Because of the two segments being procured in different years, the acquisition cost (RDT&E and Procurement) was different.

Procurement of the F16 fighter aircraft weapon system is shown in Table 2 below:

Category of Cost	10 AC (1980)	12 AC (1990)	TOTAL
Fly Away	$142.0M	$225.6M	$367.6M
Recurring	$42.6M	$67.8M	$110.4M
Non-Recurring	$14.2M	$22.6M	$36.8M
Initial Support	$28.4M	$45.2M	$73.6M
Initial Spares	$21.3M	$33.9M	$55.2M
PROCUREMENT	**$248.5M**	**$395.1M**	**$643.6M**

Table 2. Procurement Cost Summary.

C. OPERATIONS AND SUPPORT

The biggest area of leverage for the BDF and the BAAF in Reduction Total Ownership Cost (RTOC) is in the area of Operations and Support (O&S). By employing the principals of Life Cycle Management (LCM), they can influence the cost of operating

and supporting the F16 fleet. Some of the available techniques are included in the discussion to follow. The remainder of this chapter is a discussion of the elements contained in O&S costs. Also provided are the costs for each sub-category of O&S described in squadron format using the USAF Cost Oriented Resource Estimating (CORE) Model to calculate the costs. Programmatics included in the determination of the squadron annual cost, and subsequently, the TOC for the BAAF are shown in Table 3 below.

1. Personnel

The personnel element includes the cost of pay and allowances of officer, enlisted, and civilian personnel required to operate, maintain, and support a discrete operational system or deployable unit. This includes the personnel necessary to meet combat readiness, unit training, and administrative requirements. For units that operate more than one type of defense system, personnel requirements will be allocated on a relative workload basis. Personnel costs will be based on manning levels and skill categories.

1.1. **Operations Personnel:** These are the pilots and other aircrew members.

1.2. **Maintenance Personnel:** Depending on the maintenance concept and organizational structure, this element will include maintenance personnel at the organizational level and possibly the intermediate-level.

1.3. **Other Mission Personnel:** The pay and allowances of military and civilian personnel who perform unit staff, security, or other mission support functions.

OPERATIONS & SUPPORT (O&S) CALCULATIONS FOR BAAF F16 AIRCRAFT			
COST-ORIENTED RESOURCE ESTIMATING (CORE) MODEL V2.0			
Aircraft Description		**F-16**	**F-16**
Economic Year Dollars		**FY $2001**	**FY $2001**
Date		**04/28/01**	**04/28/01**
CAIG Description	**Non-Model Specific Factors**	**F-16 Del. 1980**	**F-16 Del. 1990**
Cost input includes maintenance personnel?	**No**	**Yes**	**Yes**
Program Factors			
PAA		10	12
Crew Ratio		1	1
FH/PAA/YR		180	180
Pilots/Crew		1	1
Non-Pilot Officers/Crew		0	0
Enlisted/Crew		0	0
Pilot Training Factor		$ 1,972,011	$ 1,972,011
Manpower Factors	0	340	342
PPE Officers	0	20	22
PPE Enlisted	0	320	320
PPE Civilians	0	0	0
BOS Officers		1	1
BOS Enlisted		26	26
BOS Civilians		8	8
Unit Staff Officers		4	4
Unit Staff Enlisted		14	14
Unit Staff Civilians		0	0
Security Officers		0	0
Security Enlisted		12	12
Civilian Pay	$ 46,493	$ 46,493	$ 46,493
Program Support Factors			
POL/Dollars per FH		$ 744	$ 744
General Systems Spt/FH		$ 246	$ 246
Systems Division Spt/FH		$ 129	$ 129
Training Ordnance/FH		$ 176	$ 176
Depot Level Reparables (Fixed and Variable)/FH		$ 1,687	$ 1,687
Support Equipment/PAA		$ 39,861	$ 39,861
Flyaway Cost ($M)		$ 19	$ 19
Depot Maintenance/FH		$ 107	$ 107
Depot Maintenance/PAA		$ 35,138	$ 35,138
Common Factors			
Overall Officer Turnover	0.0656	0.0656	0.0656
Non-rated Officer Turnover	0.0695	0.0695	0.0695
Installation Support Non-Pay	$ 5,788	$ 5,788	$ 5,788
Officers, Med Non-Pay	$ 3,022	$ 3,022	$ 3,022
Enlisted, Med Non-Pay	$ 3,022	$ 3,022	$ 3,022
Pilot Turnover	0.0481	0.0481	0.0481
Non Pilot Aircrew Turnover	0.0736	0.0736	0.0736
Enlisted Turnover	0.1025	0.1025	0.1025
Class IV Mod (Safety) Equation /PAA	$0	$59,778	$59,778
Officer Pay	$ 75,212	$ 75,212	$ 75,212
Enlisted Pay	$ 38,189	$ 38,189	$ 38,189
Non Aircrew Officer Training	$ 21,654	$ 21,654	$ 21,654
Enlisted Non Aircrew Training	$ 15,633	$ 15,633	$ 15,633
Maintenance Personnel	0	300	300
Organizational Officers		6	6
Organizational Enlisted		294	294

Table 3. Input Values for the CORE Model.

The annual squadron cost associated with personnel are shown in Table 4 below.

	10-F16 AC bought 1980	12-F16 AC bought in 1990
Operations Personnel	$752,120	$902,544
Maintenance Personnel	$11,678,838	$11,678,838
Unit Staff Personnel	$835,494	$835,494
Security	$458,268	$458,268
TOTAL Sqdn Pers.	**$13,724,720**	**$13,875,144**

Table 4. Squadron Level Annual Personnel Costs.

2. Unit Level Consumption

Unit-level consumption includes the cost of fuel and energy resources; operations, maintenance, and support materials consumed at the unit level; stock fund reimbursements for depot-level reparables; operational munitions expended in training; transportation in support of deployed unit training; temporary additional duty/temporary duty (TAD/TDY) pay; and other unit-level consumption costs, such as purchased services (e.g., equipment leases and service contracts).

2.1. **Petroleum, Oil and Lubricants (POL):** This is the cost of fuel for the aircraft and other lubricants used to support the squadron and its maintenance.

2.2. **Utilities:** The cost of producing/using electricity.

2.3. **Consumable supplies:** The costs of material consumed in the operation, maintenance, and support of an aircraft system and associated support equipment at the unit level. Depending on the maintenance concept or organizational structure, consumption at the intermediate level should be reported either in this element or in element 3.0, Intermediate Maintenance (External to Unit). Costs need not be identified at the level of detail shown

below; the descriptions are intended merely to illustrate the various types of materials encompassed in this element:

2.3.1. **Maintenance Material**. The cost of material expended during maintenance. Examples include consumables and repair parts such as transistors, capacitors, gaskets, fuses, and other bit-and-piece material.

2.3.2. **Operational Material**. The cost of non-maintenance material consumed in operating a system and support equipment. Examples include coolants, deicing fluids, tires, filters, batteries, paper, diskettes, ribbons, charts, and maps.

2.3.3. **Mission Support Supplies**. The cost of supplies and equipment expended in support of mission personnel. Examples include items relating to administration, housekeeping, health, and safety.

2.4. **Depot Level Reparable (DLR):** The unit-level cost of purchases of depot-level reparable (DLR) spares (also referred to as exchangeable) used to replace initial stocks. DLRs may include repairable individual parts, assemblies, or subassemblies that are required on a recurring basis for the repair of major end items of equipment.

2.5. **Training munitions and other training supplies**: The cost of expendable stores consumed in unit-level training. Includes the cost of live and inert ammunition, bombs, rockets, training missiles, sonobuoys, and pyrotechnics expended in noncombat operations (such as firepower demonstrations) and training exercises.

2.6. Table 5 below demonstrates the annual squadron costs associated with unit level consumption.

Description	Value	10 AC Squadron Annual Value	12 AC Squadron Annual Value
POL/Energy Consumption	$ -	$ 1,339,200	$ 1,607,040
POL	$ -	$ 1,339,200	$ 1,607,040
Consumable Material/Repair Parts	$ -	$ 675,000	$ 810,000
Maintenance Material	$ -	$ 675,000	$ 810,000
Aircraft Maintenance Material	$ -	$ 675,000	$ 810,000
Depot Level Reparables	$ -	$ 3,036,600	$ 3,643,920
Training Munitions/Expendable Stores	$ -	$ 316,800	$ 380,160
Unit Level Consumption	**$ -**	**$ 5,367,600**	**$ 6,441,120**

Table 5. Unit Consumption Squadron Annual Costs.

3. Intermediate Maintenance

Intermediate maintenance performed external to a squadron includes the cost of labor and material and other costs expended by designated activities/units (third and fourth echelon) in support of an aircraft system and associated support equipment. Intermediate maintenance activities include calibration, repair, and replacement of parts, components, or assemblies, and technical assistance.

3.1. MAINTENANCE. The pay and allowances of military and civilian personnel who perform intermediate maintenance on an aircraft system, associated support equipment, and unit-level training devices.

3.2. CONSUMABLE MATERIAL/REPAIR PARTS. The costs of repair parts, assemblies, subassemblies, and material consumed in the maintenance and repair of aircraft, associated support equipment, and unit-level training devices.

3.3. OTHER. Include in this element any significant intermediate maintenance costs not otherwise accounted for.

NOTE: The intermediate costs for BAAF are included in Unit Consumption.

4. Depot Level Maintenance

The labor, material, and overhead costs for overhaul or rework of aircraft returned to a centralized depot facility. Includes programmed depot maintenance, analytic condition inspections, and unscheduled depot maintenance. Costs of major aircraft subsystems that have different overhaul cycles (i.e., airframe, engine, avionics, armament, support equipment) should be identified separately within this element. It is important to note the majority of depot costs (DLRs) is displayed in the Unit Consumption portion of the cost estimate. This is due to the squadrons having to be accountable for the LRU repairs/replacement that are sent to the depot. Table 6 below identifies the current annual squadron depot maintenance cost.

Description	Value	10 AC Squadron Annual Value	12 AC Squadron Annual Value
Depot Maintenance	$ -	$ 543,980	$ 652,776

Table 6. Depot Maintenance Squadron Annual Costs.

5. Contractor Support

Contractor support includes the cost of contractor labor, materials, and overhead incurred in providing all or part of the logistics support required by an aircraft system, subsystem, or associated support equipment. Contract maintenance is performed by commercial organizations using contractor personnel, material, equipment, and facilities or government-furnished material, equipment, and facilities. Contractor logistics support (CLS) if the support extends over the operational life of a system. Other contractor support may be purchased for engineering and technical services.

5.1. CONTRACTOR LOGISTICS SUPPORT. Contractor logistics support (CLS) includes the burdened cost of contract labor, material, and assets used in providing support to an aircraft system, subsystem, and associated support equipment. CLS funding covers depot maintenance and, as negotiated with the operating command, necessary organizational and intermediate maintenance activities.

5.2. OTHER. Include in this element any contractor support costs not otherwise accounted for. For example, if significant, the burdened cost of contract labor for contractor engineering and technical services should be reported here.

Notes:

1. The BAAF assumes responsibility for supporting a weapon system. However, contractor support may still be employed in specific functional areas, such as sustaining engineering, software maintenance, simulator operations, and selected depot maintenance functions. Applicable contractor costs should be reported against these elements in the Cost Element Structure (CES). To avoid double counting, the contractor support element should be annotated to identify any contractor costs that are reported in other elements.

2. There is no contractor support estimated since the aircraft have been in BAAF for 11 or more years.

6. Sustaining Support

Sustaining support includes the cost of replacement support equipment, modification kits, sustaining engineering, software maintenance support, and simulator

operations provided for an aircraft system. War readiness materiel is specifically excluded.

6.1. SUPPORT EQUIPMENT REPLACEMENT. The costs incurred to replace equipment that is needed to operate or support an aircraft, aircraft subsystems, training systems, and other associated support equipment. The support equipment being replaced (e.g., tools and test sets) may be unique to the aircraft or it may be common to a number of aircraft systems, in which case the costs must be allocated among the respective systems.

6.2. MODIFICATION KIT PROCUREMENT/INSTALLATION. The costs of procuring and installing modification kits and modification kit initial spares (after production and deployment) required for an aircraft and associated support and training equipment. Includes only those modification kits needed to achieve acceptable safety levels, overcome mission capability deficiencies, improve reliability, or reduce maintenance costs. Excludes modifications undertaken to provide additional operational capability not called for in the original design or performance specifications.

6.3. OTHER RECURRING INVESTMENT. Include in this element any significant recurring investment costs not otherwise accounted for.

6.4. SUSTAINING ENGINEERING SUPPORT. The labor, material, and overhead costs incurred in providing continued systems engineering and program management oversight to determine the integrity of a system, to maintain operational reliability, to approve design changes, and to ensure

system conformance with established specifications and standards. Costs in this category may include (but are not limited to) government and/or contract engineering services, technical advice, and training for component or system installation, operation, maintenance, and support.

6.5. SOFTWARE MAINTENANCE SUPPORT. The labor, material, and overhead costs incurred after deployment by depot-level maintenance activities, government software centers, laboratories, or contractors for supporting the update, maintenance and modification, integration, and configuration management of software. Includes operational, maintenance, and diagnostic software programs for the primary system, support equipment, and training equipment. The respective costs of operating and maintaining the associated computer and peripheral equipment in the software maintenance activity should also be included. Not included are the costs of major redesigns, new development of large interfacing software, and modifications that change functionality.

6.6. SIMULATOR OPERATIONS. The costs incurred to provide, operate, and maintain on-site or centralized simulator training devices for an aircraft system, subsystem, or related equipment. This may include the labor, material, and overhead costs of simulator operations by military and/or civilian personnel, or by private contractors.

6.7. OTHER. Include in this element any significant sustaining support costs not otherwise accounted for. Examples might include the costs of follow-

on operational tests and evaluation, such as range costs, test support, data reduction, and test reporting.

6.8. Table 7 displays the annual sustaining support cost per squadron.

Description	Value	10 AC Squadron Annual Value	12 AC Squadron Annual Value
Support Equipment Replacement	$ -	$ 398,610	$ 478,332
Modification Kit Procurement/Installation	$ -	$ 597,780	$ 717,336
Other Recurring Investment	$ -	$ -	$ -
Sustaining Engineering Support	$ -	$ -	$ -
Software Maintenance Support	$ -	$ -	$ -
Simulation Operations	$ -	$ -	$ -
Sustaining Support	**$ -**	**$ 996,390**	**$ 1,195,668**

Table 7. Sustaining Support Squadron Annual Costs.

7. Indirect Support

Indirect support includes the costs of personnel support for specialty training, permanent changes of station, and medical care. Indirect support also includes the costs of relevant host installation services, such as base operating support and real property maintenance. This is an area that can be affected by consolidating some functions and locations for the two squadrons and realize some O&S cost savings. This will be discussed later. Table 8 below displays these costs.

Description	Value	10 AC Squadron Annual Value	12 AC Squadron Annual Value
Personnel Support	$ -	$ 2,628,659	$ 2,824,411
Medical Support	$ -	$ 1,109,156	$ 1,115,200
Medical Support Non-pay/Material	$ -	$ 1,109,156	$ 1,115,200
Specialty Training	$ -	$ 1,519,504	$ 1,709,211
Pilot Training	$ -	$ 948,537	$ 1,138,245
Non-Aircrew Training	$ -	$ 570,966	$ 570,966
Non-Aircrew Training Officer	$ -	$ 16,554	$ 16,554
Non-Aircrew Training Enlisted	$ -	$ 554,412	$ 554,412
Installation Support	$ -	$ 3,610,570	$ 3,622,146
Base Operating Support Personnel	$ -	$ 1,440,070	$ 1,440,070
BOS Military Personnel	$ -	$ 1,068,126	$ 1,068,126
BOS Civilian Personnel	$ -	$ 371,944	$ 371,944
Installation Support Non-Pay Personnel	$ -	$ 2,170,500	$ 2,182,076
Indirect Support	**$ -**	**$ 6,239,229**	**$ 6,446,557**

Table 8. Indirect Support Squadron Annual Costs.

D. DISPOSAL

This captures costs associated with deactivating or disposing of a military system at the end of its useful life. These costs typically represent only a small fraction of a system's life-cycle cost and are excluded from most analyses.

Moreover, disposal cost is difficult to quantify. This is due to several factors, including the following First, the weapon system could be sold to another country, thereby negating the disposal cost which then becomes an asset and a reduction to the TOC. Secondly, the weapon system could be dismantled and used in other areas of the BDF. Again, this would constitute an asset because it is being used somewhere else in the BDF. But, it would be offset by the cost of dismantling the weapon system.

Hazardous material costs of disposal are contained in the O&S portion of the cost estimate and, therefore, in this portion of the TOC.

E. TOC SUMMARY

The current annual costs associated with the BAAF F16 fleet is shown in Table 9 below.

		F16 (1980)	F16 (1990)
Squadron Total ($/YR)	**$ -**	**$ 26,871,919**	**$ 28,611,265**
Annual BAAF F16 Fleet Cost			**$ 55,483,184**

Table 9. Annual BAAF F16 Fleet Cost.

The TOC remaining for the F16 fleet in the BAAF can therefore be shown in millions of US $ in Table 10 below.

		10 AC Sqdn	12 AC Sqdn
Squadron Total ($/YR) ($M)		**$26.9**	**$28.6**
Remaining FH of Service		42200	72240
Remaining Years of Service		23	33
Squadron Total ($M)		**$618.05**	**$944.17**
BAAF TOTAL ($M) for Remaining Life of F16 Fleet			**$1,562.23**

Table 10 TOC Remaining BAAF F16 Fleet Cost.

By making some adjustments in the installation operations for the F16 fleet and by consolidating some squadron level functions (especially in the intermediate level operations), savings can be realized. Table 11 below shows the CORE cost model input changes that the BAAF might possibly make to reduce O&S costs, and therefore reduce the TOC. Changed items are shown in bold. By consolidating installation functions, reducing base support personnel, utilizing more simulation training, and reducing the frequency of replacing support equipment, and downsizing the maintenance and operations personnel, substantial savings are potentially available.

	BAAF	BAAF	BAAF Adjusted	BAAF Adjusted
	Squadron #1	Squadron #2	Squadron #1	Squadron #2
Manpower Factors	340	342	340	**186**
PPE Enlisted	320	320	320	**164**
BOS Enlisted	26	26	26	**13**
BOS Civilians	8	8	8	**4**
Security Enlisted	12	12	12	**3**
Training Ordnance/FH	$ 176	$ 176	**$ 44**	**$ 44**
Support Equipment/PAA	$ 39,861	$ 39,861	**$ 4,983**	**$ 4,983**
Non Aircrew Officer Training	$ 21,654	$ 21,654	**$ -**	**$ -**
Enlisted Non Aircrew Training	$ 15,633	$ 15,633	**$ -**	**$ -**
Maintenance Pers	300	300	300	**153**
Organizational Enlisted	294	294	294	**147**

Table 11. Recommended Changes in Operations.

The reductions discussed above results in the savings identified in Table 12 below. This is the essence of the LCM discussed throughout this paper. By continuous management of the fleet costs, adjustments may be found that can further reduce the TOC. Included in this management is the monitoring of modifications and upgrades being conducted by the USAF that may be useful to the BAAF and create additional O&S savings.

		10 AC Sqdn	12 AC Sqdn
Squadron Total ($/YR) ($M)		**$25.0**	**$18.3**
Remaining FH of Service		42200	72240
Remaining Years of Service		23	33
Squadron Total ($M)		**$575.07**	**$604.92**
BAAF Total ($M) for Remaining Life of F16 Fleet			**$1,179.99**

Table 12. Revised TOC for F16 BAAF Fleet.

This suggests a savings of $382.23M US dollars (more than a quarter billion dollars) over the remaining life of the F16 fleet. Possibly more savings can be realized

from studies using data based on actual BAAF practices and through continuous management of the weapon system. For more details see Appendix A.

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VI. BAAF O&S COST DRIVERS

A. INTRODUCTION

There are many factors that affect the TOC of a weapon system. This chapter will present those elements that are major factors in the LCM of the TOC. It will discuss those items that affect the TOC the most (cost drivers), and will show how decisions made by LCM that can positively or negatively affect the TOC. As has been discussed earlier, failure to pay attention to these elements will, most probably, result in higher than necessary TOC for the BDF and the BAAF. The better the weapon system (F16 fighter aircraft and its support) is managed, the better the possibility of having funds for additional items within the BDF. These cost drivers, and the reason for them being the highest cost drivers, must be continually managed or else dire consequences will occur.

1. Definition

First, it is essential to understand what cost drivers are and what causes them to be cost drivers. A cost driver is a program, system characteristic, or parameter that has the direct or indirect effect of changing cost. A cost driver may even be another cost element. Examples of cost drivers include numbers of systems, numbers of operating sites, numbers of systems failures, time to fix broken systems, etc. The cost of operations and support is driven by the cost of individual spare parts and by the labor-hour costs of operators and maintainers. Thus, one cost category drive another. In some instances, the term "cost drivers" means all parameters and characteristics that drive costs; but, in some cases, the "cost drivers" is intended to differentiate the parameters/characteristic with the most impact on costs. Cost drivers are those costs that create the greatest cost to the squadron, the wing, the BAAF, and the BDF. They are normally expressed as the top 25

or top 50 cost drivers. Many things and decisions had circumstances result in the creation of cost drivers. It must be remembered that there is always going to be a highest cost item. This LCM is the natural order of things. This does not mean to imply those changes with LCM should surrender without a fight, quite the contrary. Each cost must be continually monitored and every attempt made to reduce it to the lowest possible value. In this evaluation, the elements that affect that cost must also be monitored. These items are:

2. Logistics

(Getting the Right Thing to the Right Place at the Right Time).

This is the total support provided to the weapon system, regardless of where it is performed. This support begins with the decisions of where the support would best serve the needs of the BAAF and yet be the most efficient and lowest cost. One of the decisions that must be made relates to the support concept employed with the F-16 weapon system. Included in the support concept is where will the item being evaluated be supported, in-country or out-of-country.

a. In-Country

In country means the item or the function being evaluated will be provided/supported within the country of Bahrain. This does not mean that every element of the item must be built and stored in Bahrain. Parts of the item may well be purchased from a foreign vendor but the support of the item would be accomplished within Bahrain. For example, the mission computer may have Line Replaceable Modules (LRM) that are built out-of-country but the computer itself, including the maintenance, repair, assembly, and testing of the computer would be accomplished in Bahrain.

b. Out-of-Country

The converse to in-country support is out-of-country. This means the item is built, maintained, repaired, assembled, and tested out-of-country. The only actions taken within Bahrain are the removal, ship, and re-installation of the part. There are times when this support solution is the most affordable and probably the lowest cost. For example, some parts that are mass produced to service many countries would probably be the lowest cost to the BAAF who would only be building a few of the items. Another consideration is the complexity of the item. Highly complex assemblages normally are best left to the contractor that knows the item the best, and has the greatest experience base in the testing and repairing of the item. For these items, it would probably have a considerable capital investment for the BDF and the BAAF, to say nothing about the time (labor) to test and repair the item due to lack of familiarity with the fault isolation and testing processes.

3. Affordability

Affordability is the ongoing assessment of a system to ensure that it is operable and supportable within LCC guidelines.

What makes an item affordable? The simplest way of describing this is to say this is what the customer / user is willing and capable to pay. A beggar on the street could not afford to purchase any home, but a president of a corporation could probably afford a mansion. The BAAF could not afford the Air Force found in the US, but could definitely afford a better Air Force than the Isle of Capri. The United States Department of Defense (DoD), Dr. Gansler, explained this as:

> For many years, a disciplined management approach has existed for acquiring systems and material to satisfy Air Force needs. These acquisition processes allowed the Air Force to obtain affordable systems.

> However, these processes are not sufficient to meet today's challenges. The Air Force must reduce Total Ownership Cost (TOC) in order to meet affordable readiness goals and create investment opportunities. TOC includes the cost of research, development, acquisition, test and evaluation, operation and support (O&S), and disposal costs. Once these costs are identified and understood, the Air Force can: 1) identify system design/sustainment options ("trade space"); 2) determine where waste/non-value added processes exists; and 3) make smart decisions to reduce future costs, eliminate waste, and recapture dollars.
>
> A team effort is required to effectively implement significant cost reductions. PM's, field activities, depots, MAJCOMs (Major Command), and Air Staff are all part of the team, and they all control costs either directly or indirectly. No single activity has direct control over all costs. The PM can serve as a focal point to gather and present information to show the history, current status and trends of his/her program's posture.
>
> TOC is an important concept and requires everyone's understanding. By working together as a team, the Air Force can make the changes needed to maintain readiness required supporting national objectives and sustaining the Air Force well into the 21st century.[39]

This must be expanded to relate to Foreign Military Sales (FMS) as well. We all need to work together in order to achieve the best affordability for Bahrain as well as the US.

Acquisition management system provides a streamlined, event-driven management structure that emphasizes risk management and affordability. It explicitly links milestone decisions to demonstrated accomplishments. The activities that are managed by this system are illustrated in Figure 19.

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[39] Air Force Reduction in Total Ownership Cost (R-TOC); CAIV/TOC Guidebook; (Version 1.0); 27 May 1999, Dr. J. Gansler.

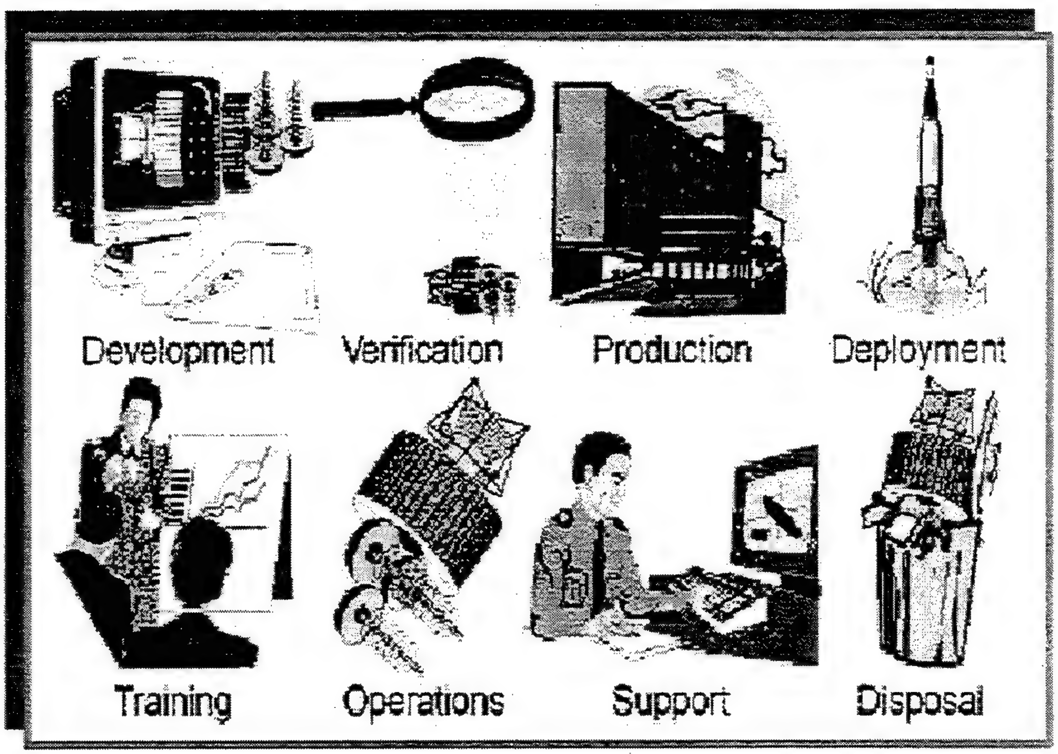

Figure 19. Acquisition Management Activities[40].

The following issues should be addressed early in the acquisition cycle to meet operational requirements and to reduce life-cycle costs:

*a. **Reliability***

The probability that an item will perform its intended functions for a specified period under stated conditions. Simply stated, it is how long the system can work. Mean Time Between Failure (MTBF) is commonly used to define the total functioning life of a population of an item during a specific measurement interval divided by the failures during that interval. The failure rate (Greek letter lambda) is defined as the number of item failures of per measure of unit life.

---

[40] Air Force Instruction (AFI) 65-503, Cost Planning Fact.

Failure rate can be calculated as follows:

Failure rate = 1/MTBF (failures over time)

(Failure rates of components in series are additive)

Reliability can be further broken down into mission reliability and logistics reliability:

- **Mission Reliability.** The probability that a system will perform mission-essential functions for a period of time under the conditions stated in the mission profile. Measures of mission reliability include only those incidents affecting mission accomplishment.

- **Logistics reliability** is the probability that no corrective maintenance or unscheduled supply demand will occur following the completion of a specified mission profile.

Reliable systems result in increased combat capability while requiring fewer spare parts and personnel. Maintainable systems require fewer people and specialized skills; it also reduces maintenance times. These reductions result in lower ownership costs. The advantages go beyond the system itself. Large, complex combat support structures are vulnerable to attack. Reliable systems mean reduced dependence on airlift and pre-positioning. Reliability requirements address both mission reliability and logistics reliability.

Simply put, how often an item breaks is an indication of that item's reliability. A high reliability means the part can go for a long period of time before it breaks or needs maintenance. Obviously, the higher the reliability is, the more desirable

the item becomes. One problem associated with a high reliability is that it more than likely will cost considerably. Therefore, as is with any budgeting process, the determination must be made regarding what level of reliability is affordable. However, there are many things that can increase the reliability of an item without it being cost prohibitive. Advances in technology is certainly one way of improving the reliability of the item. Another is to allow the manufacturer to maintain their item but maintain form, fit, function, and integration (F3I) under a contractor type contract. This would, in essence, mean the contractor would be incentivized to improve the reliability of the item. Reliability data is gathered and provided in a host of ways, such as the RAMDATA report provided by the USAF. It is totally impossible to even begin to discuss the complete reliability data collected by the USAF. However, Figure 20 below is a sample set of the RAMDATA database to illustrate the data available. The LCM must continually monitor the reliability of the F-16 weapon system. This would hopefully result in identification of those items which need further attention with the purpose of improving the reliability to an acceptable level. The less the item breaks, the less cost of having to remove the item, ship the item (if necessary), and repair the item.

WUC	CND	EVENTS	CND RATE	BCSSHOP	SHOP	BCS RATE
A/C	2279	16550	0.1377	436	3704	0.1177
74A	208	754	0.2759	56	303	0.1848
74AH0	.	.	0	.	.	0
74AM0	12	90	0.1333	5	50	0.1
74ANP	0	1	0	0	0	0
74AN0	6	130	0.0462	25	92	0.2717
74AP0	4	127	0.0315	15	96	0.1563
74AQ0	0	0	0	0	1	0
74ASA	0	1	0	0	0	0
74ASC	.	.	0	.	.	0
74ASD	0	3	0	0	0	0
74ASE	1	4	0.25	0	1	0
74ASG	0	1	0	0	0	0
74AS0	0	1	0	0	0	0
74AT0	0	4	0	0	0	0
74AU0	0	4	0	0	0	0
74AV0	1	2	0.5	0	0	0
74AY0	14	145	0.0966	11	62	0.1774
74A00	169	224	0.7545	0	1	0
74A99	1	17	0.0588	0	0	0

Figure 20. Sample Set of RAMDATA.

b. Maintainability

The probability that if prescribed procedures and resources are used, an item will be retained in, or restored to, a specific condition within a given period. It is the inherent characteristic of a finished design that determines the amount of maintenance required to retain or restore the system into a specified condition. Corrective maintenance can be measured by Mean Time to Repair (MTTR); or, stated in more simple terms, how quickly and easily the system can be fixed. Also, Mean Maintenance Time (MMT) not only includes corrective maintenance but also accounts for preventive maintenance.

As with reliability, maintainability must be closely managed by the LCM process. Here, Bahrain must find the delicate balance between the operational requirements and the logistics maintaining the item. Maintainability is the amount of time used to maintain, remove, repair, test, and reinstall. Again, there is a need for

balance between the operational requirements (Mission Ready status, etc.) and the cost of the maintainability support. The right number of personnel, with the right skills, in the right place are some of the factors that must be considered by the LCM.

c. ***Supportability***

This is where the decisions such as those discussed earlier are determined and continuously evaluated. Whether or not to have an item supported in-country or out-of-country is one aspect of supportability. Another aspect is those items discussed earlier about the possible savings that can be realized by the consolidation of functions and the elimination of duplicate functions. LCM must continually monitor the support system to insure it is providing the highest possible supportability to the BDF and the BAAF. A support plan is necessary that would address each and every support requirement with regards to who is going to perform the function, where will the function be performed, when will this support be available, how many support personnel are required, etc.

An important aspect is the early integration of *supportability considerations* into the system design concept. As illustrated in Figure 21 the decisions made during impact approximately 60% of total life cycle costs. As shown in Figure 22, much of these costs are incurred during the operations and support phase.

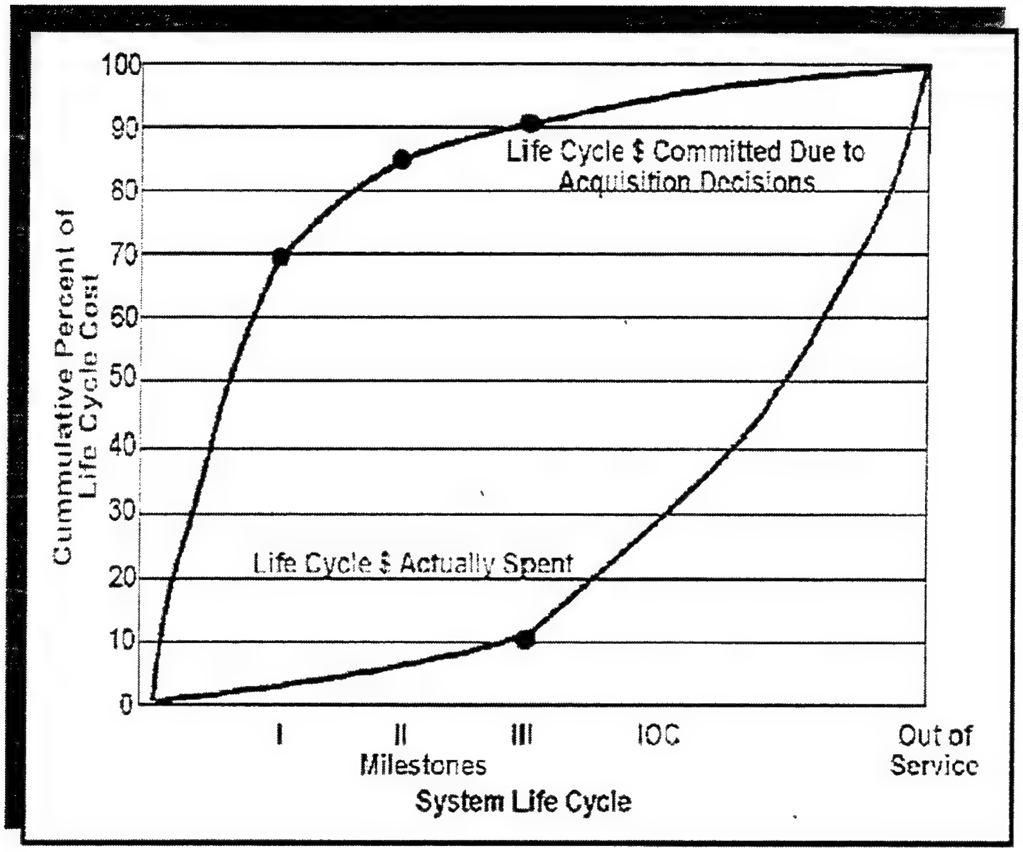

Figure 21. Effect of Early Decisions on Life Cycle Cost.

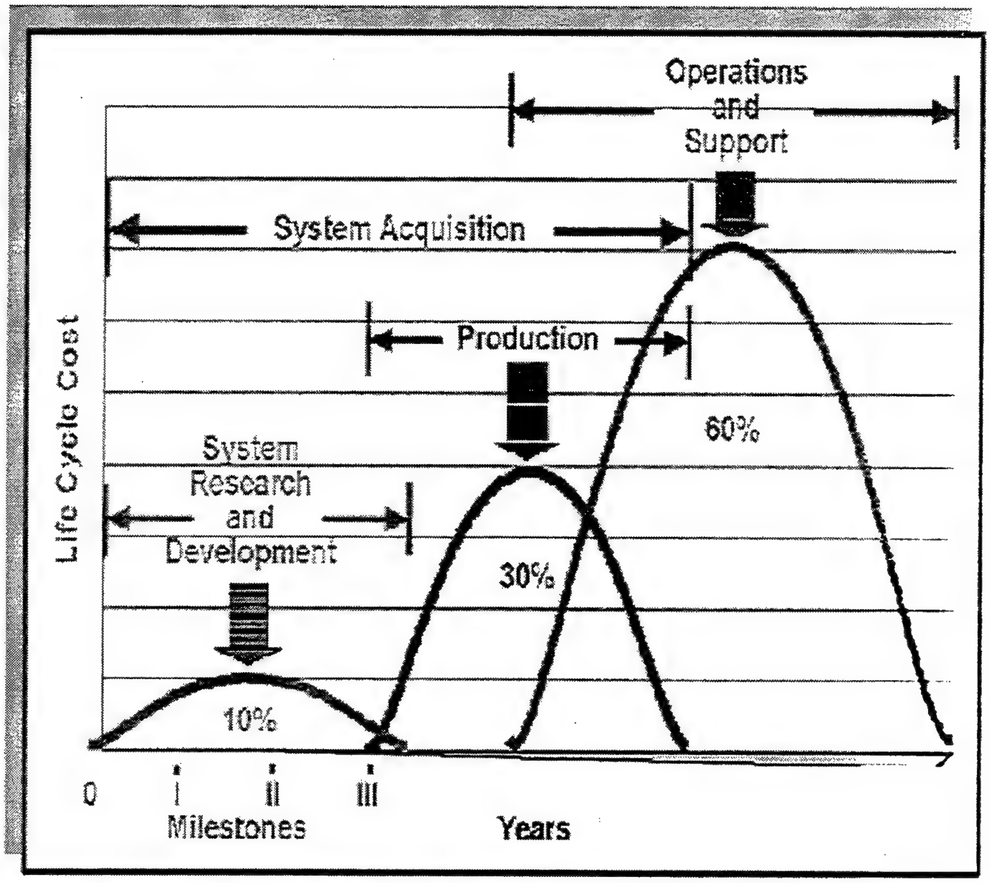

Figure 22. Nominal Cost Distribution of a Typical Program.

The supportability of the F-16 weapon system is also predicated on one subject that should be singled out due to it being one of the cost drivers of the system, that of software maintenance. A tremendous amount of effort and LCM goes into the control, management, and decision making of software maintenance. Software maintenance is described as:

> The labor, material, and overhead costs incurred after initial deployment by the depot level maintenance activity government software centers, laboratories, or contractors for supporting the update, maintenance, and diagnostic software programs for the primary system, support equipment and training equipment. The respective costs of operating and maintaining the associated computer and peripheral equipment in the software maintenance activity should also be included. Costs that should not be

included are major redesigns, new development of large interfacing software and modifications that change functionality.[41]

Model and Simulation (M&S) supports the transition from design to initial production and testing. Engineering level models are used for performance analysis, test planning, and test support. Figure 23 below describes the methodology used in conducting M&S.

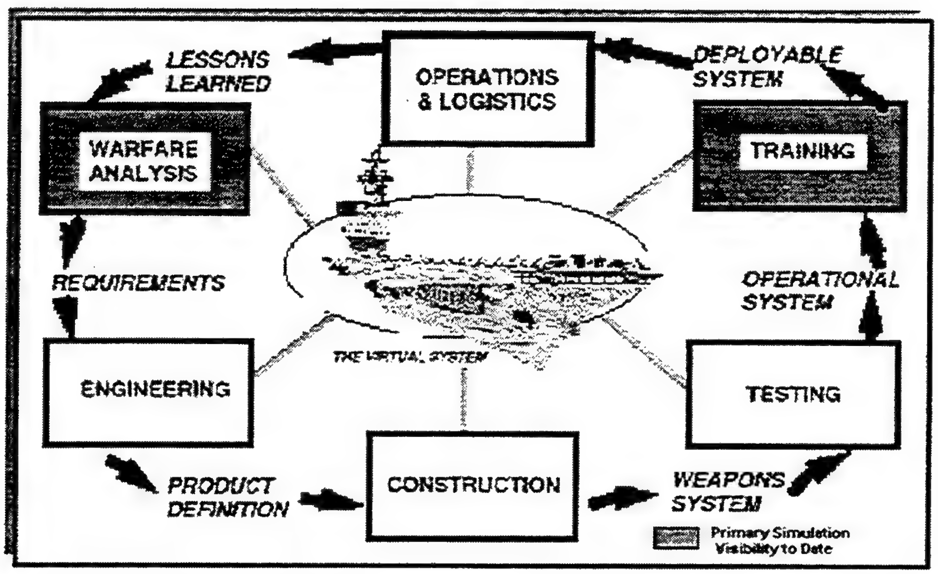

Figure 23. Virtual M&S Design in the System Life Cycle.

Software development occurs at the beginning of the life cycle, Milestone 0. The software packages necessary for the Bahrain F-16 weapon system to be operational was provided in the initial support package. Thus, a core capability is fielded, where the system is designed modularly, and provisions are made for upgrades and changes. This started the period of software maintenance for the BAAF. Figure 24 illustrates Pressman's interpretation of the evolutionary model where a first generation

[41] DoDD 5000.1, Chapter 5 System Life Cycle and Methodologies 5.1 -- Life Cycle Process and Decision Making.

spiral evolves into an extended second generation spiral, and so on.[42] This continues throughout the life cycle of the weapon system except the last few years prior to disposal where it would not be economically feasible to perform any more software modifications or upgrades (i.e. software maintenance). As can be readily seen, strong and effective LCM must be employed to manage the software maintenance of the weapon system, which includes the F-16 aircraft and all of its support equipment.

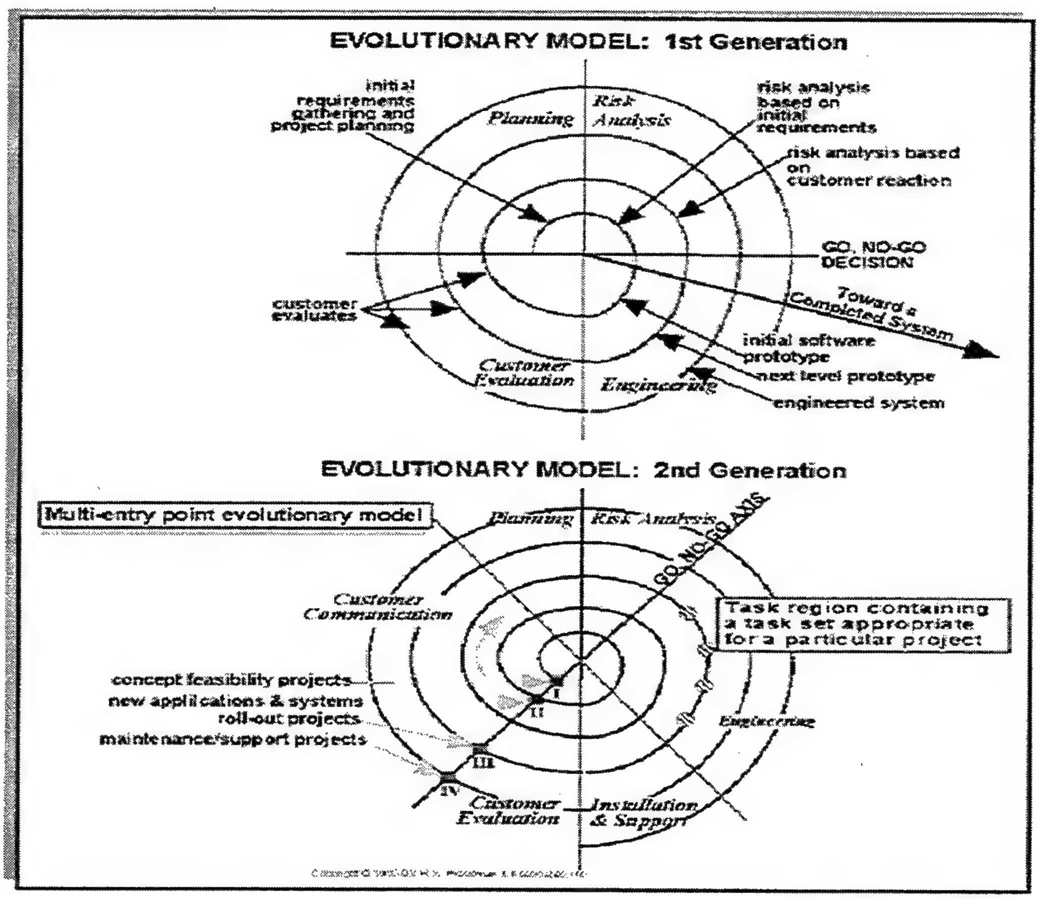

Figure 24. Evolutionary Life Cycle Generations.

[42] Guidelines for Successful Acquisition and Management of Software-Intensive Systems:; Volume 1 – Version 3.0; May 2000, 5.6.1 -- Evolutionary Method.

Evolutionary programs progress towards an ultimate capability. This strategy requires the development of increments of software that are demonstrable to the BAAF, which is involved throughout the entire development process, as illustrated in Figure 25. It must be remembered that each software modification and upgrade requires development to some degree. This causes the software to remain involved in the evolutionary process and causes the continuation of the LCM for the software. BAAF must work closely with other FMS countries using the F-16 to effect and control the software modifications being made. It is in the BDF and BAAF interest to enter into some software maintenance agreements for co-payment with the USG and the FMS countries involved in order to reduce the TOC for the software maintenance.

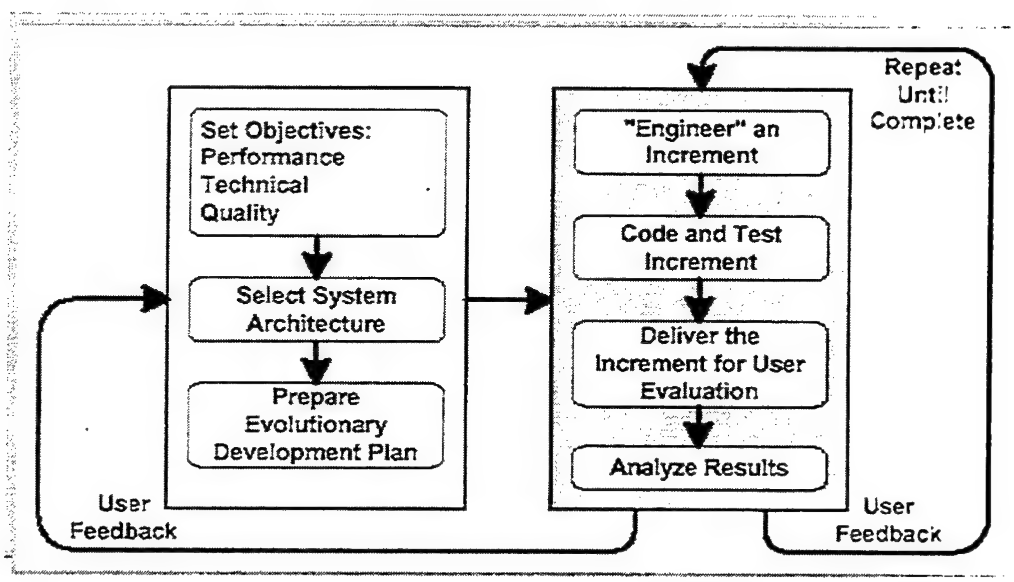

Figure 25. User Involvement in the Evolutionary Method[43].

[43] Guidelines for Successful Acquisition and Management of Software-Intensive Systems:: Volume 1 – Version 3.0; May 2000, 5.6.1 -- Evolutionary Method.

When used effectively, the evolutionary model can provide significant interrelated benefits. Examples of benefits include the following:

- Improved requirements. Requirements for software modifications can be generated by the addition of other capabilities, such as a new missile, radar, etc.

- Technology insertion. In the world today, technology is moving forward at a very high rate of speed. It would not be economically possible to keep up with all the technologies being developed.

- Management control and program visibility. Once again, the process of good and effective LCM must be employed. Only those essential technologies that fit with the BDF and BAAF defense plans should be considered for purchase.

- Improved system quality. The continuous concentration on BDF and BAAF requirements normally is executed through the LCM process integrating with the developer (probably, the USG and the USAF). This BAAF involvement results in improved system quality.

d. Availability

Based on the question, "Is the equipment available in a working condition when it is needed?" Availability is defined as the probability that an item is in an operable and commitable state at the start of a mission when the mission is called for at a random point in time. The user is most concerned about this parameter. This reflects the readiness of the system. There are a number of definitions of availability, and it is important to understand the basic ones. All are based on this standard mathematical

relationship, with differing definitions of the terms "Up Time;" "Down Time;" and "Total Time":

$$\text{Availability} = A = \frac{\text{Up Time}}{\text{Total Time}} = \frac{\text{Up Time}}{\text{Up Time} \div \text{Down Time}}$$

One measure in particular, Operational Availability (Ao), covers all time segments the equipment is intended to be operational. As seen by the following equation, operational availability is based on a mathematical relationship among three characteristics: reliability, maintainability, and the effectiveness of the logistics support system. Reliability is measured as the mean operating time plus mean standby time in an operational condition (represented by Mean Time Between Maintenance (MTBM)). Maintainability includes the mean maintenance time for both corrective and preventive actions (represented by Mean Maintenance Time (MMT)). Logistics support effectiveness is the combination of the logistics delay time plus any administrative delays (represented by Mean Logistics Down Time (MLDT)). The Mean Time Between Maintenance (MTBM) is based on all maintenance actions, whether corrective or preventative in nature.

4. Training

Training consideration begins at Milestone 0 and continues throughout the life of the system. Initial training must be well thought out in all aspects such as: Who needs the training, how often should the training be conducted, where should it be conducted. In Bahrain, the pilots and support personnel had to be trained prior to the receipt of the F-16 fighter aircraft. These personnel became responsible for the training of the follow-on personnel. Personnel who were trained on other aircraft would receive a different

training course than those who have never been with another aircraft. Some of the items for consideration are shown below:

- Pilot initial training
- Pilot cross training
- Pilot refresher training
- Crew initial training
- Crew cross training
- Crew refresher training
- Maintainer initial training
- Maintainer cross training
- Training device procurement
- Training device operations
- Training device upgrades, modifications, repair

B. IDENTIFICATION OF COST DRIVERS

Cost drivers are determined by using historical data to demonstrate and identify those costs that are creating the highest costs. Data collection and good LCM will produce the information needed to identify these drivers. By identification of the drivers, LCM practices and policies can be brought to bear on trying to reduce these cost to maximum extent possible.

Figure 26 below identifies collected information on cost drivers for the F-16 aircraft. These cost drivers change due to the impact of LCM being applied. LCM continuously monitors these drivers in an attempt to find ways to reduce the TOC.

Work Unit Code (WUC)	Description	Total Removal Count	I-Level Retest OK	Removal Rate per 100 Flight Hours	% of total AC
13DAO	Main Landing Gear Wheel/Tire Assy	548	0	4.908	3.3
13KAO	Main Landing Gear Wheel/Tire Assy	625	0	1.866	3.8
42GAA	Battery, Aircraft	205	0	1.836	1.2
13DBO	Nose Landing Gear Wheel/Tire Assy	181	0	1.621	1.1
74NOO	Lantirn Targeting Pod	241	14	1.266	1.5
13KAB	Tire	345	0	1.03	2.1

Figure 26. Sample Set of Removal Rate for Suspected Failure.

It is important to realize the above information is a small sample set of the data collected on the F16 aircraft. For proper LCM to be employed, this type of reliability data must be evaluated continuously. Failure to do this would result in the continuation of the high cost drivers without possible reduction. This, surely, would result in higher than necessary O&S costs. It is essential within the BAAF that every effort, by the BAAF and by the USAF, be brought to bear on the reduction of these costs to the bare minimum. Some costs are very difficult to reduce within an active fleet, such as the batteries and tires. Of course, over a period of time, even those costs can be reduces as research and development produces new techniques and technologies that could be brought to bear.

C. DISCUSSION

There are many items to consider regarding the LCM of a weapon system. No longer is it acceptable to simply operate the weapon system. The system must be ready

to go at any time. Many decisions had to be made by the BAAF at the time of purchase of the F-16 aircraft. There are also many decisions that must be accomplished every day. At no time, should there be a situation of complacency allowed to develop in the operational and support structure involved in the F-16 for the BAAF. There are thousands of items to be managed that belong to the F-16. BAAF must continue to find ways to monitor and collect data necessary for LCM to properly perform. Each squadron must evaluate its operational procedures to insure there are no redundancies that can be eliminated. Each squadron must be held fiscally accountable for its operation. Data collection efforts must be continuously monitored to insure accurate data available to management. Support is not something that simply happens as a by-product of an acquisition. It must be meticulously developed and monitored. Each squadron in the BAAF must be aware of the cost drivers and how that came about. They must be involved in the reduction of costs across the board, not just with the cost drivers. Failure to pay strict attention will result in excessive expenditures.

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VII. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

This thesis presents a general scheme for Life Cycle Management (LCM) in the Bahrain Defense Force (BDF) and Bahrain Amiri Air Force (BAAF), with specific attention paid to the F16 fighter weapon system. Life Cycle Management (LCM) is a very effective tool to identify, track, and manage the Total Ownership Cost (TOC) if decision makers such as wing commanders know how to use it and implement it properly.

LCM is the language that best deals with Reduction in Total Ownership Cost (R-TOC). The Bahrain Defense Force (BDF), represented by the Bahrain Amiri Air Force (BAAF), can utilize Life Cycle Management (LCM) to a great advantage in reducing its Total Ownership Cost (TOC). LCM is a management technique designed to manage and control all aspects of any program. In this thesis, discussion of LCM is concentrated on the Bahrain Amiri Air Force (BAAF) F-16 fighter aircraft fleet. Even though the F-16 fleet was purchased years ago, there are many modifications and upgrades that are currently ongoing, both within the United States Air Force (USAF), other countries, and the BAAF. The adaptation and employment of LCM principles can help avoid unnecessary BDF expenditures. To realize this potential, processes must be put in place and refined that will identify cost drivers and other high expenses. Through LCM, these drivers and expenses can be examined and analyzed to look for and find solutions that may reduce or save assets, budget funds being one of them. Efficiency and proficiency is another result of proper development and use of LCM processes.

B. RECOMMENDATION

Before listing the recommendations that can help the BAAF in implementing and utilizing LCM, I would like first to identify and analyze four critical challenges that the BAAF encounter which have a direct impact on employing the LCM. The BAAF address these challenges energetically in order to gain the maximum benefit from applying the LCM. These four challenges are as follow:

1. Logistics

Obviously every unit or any air force, must keep its supply readily available to support operations during unexpected circumstances or emergency. To maintain operational capability, the BAAF has to address the problem of cost and delay in turnaround of the spare parts sent for out-of-country repair. Also, the long time it takes to order new spare parts, plus unexpected failures, and grounding the aircraft, must be taken into account. This lost time means delayed training for both pilots and technicians. These kinds of problems confuse and complicate the operational and administrative situation for both maintenance and operations. Logistics deficiencies generate undesired options of canceling the missions or operations, and forces cannibalization. Though sometimes necessary, cannibalization is very risky, because of the probability that the cannibalized part could break is quite high.

2. Training

Military forces need a lot of time to "digest" and deal with a new weapon or system. In many cases, a great deal of money has to be spent acquiring the skills and experience necessary to maintain and use a complex weapon or system effectively. The BAAF is one of those organizations. A lot of money was spent to offer quality training for both pilots and technicians. To complicate matters, training was not always available

or could not be accomplished in Bahrain. Lack of funding sometimes caused more difficulties in acquiring very much needed training.

Training is a never-ending requirement regardless of individual experience. Examples are training pilots to the level of experience, confidence, and proficiency to deal effectively with the enemy which requires fuel, bombs, missiles, and bullets for practicing. This is expensive. Also, each pilot needs time and training to acquire the arts and tactics of the air-to-air battle. For the maintenance technician, a lot of training is required to become competent at diagnosing and troubleshooting his assigned system. Problem solving and proper repair of defective components also requires extensive training depending on the repair level. Speed of repair is also needed at some levels of maintenance, which requires ongoing training to accomplish the task correctly and quickly.

3. Up-Grades and Technology

Bahrain, like other countries, has to keep pace with changes and up-grades or otherwise watch its systems degrade and become ineffective. The BAAF F-16 aircraft has already completed 10 years of service. To keep the BAAF F-16 fleet hardware up-to-date, the challenges of upgrading are being met with the "FALCON-UP" program.

Intelligent upgrades require sensitive decisions and precise accounting. since the program is both costly and critical. Second, a plan must be created to manage the F-16 for its entire life in service through retirement. How much it will cost has to be addressed and studied. What other alternatives and options are available must be looked at.

4. Manpower

The BAAF today is continuously expanding and the scarcity of trained manpower available constitutes an obstacle. It also imposes significant pressure on the existing

maintenance force. Therefore, a plan is needed to manage and overcome the ongoing manpower problem, especially after the arrival of the second new wave of F-16 aircraft.

When making the decision to acquire the F-16 aircraft for the Bahrain Defense Force (BDF) and the Bahrain Amiri Air Force (BAAF), an immediate problem was where to obtain skilled manpower to adequately staff a multitude of jobs needed to support F-16 aircraft. Local personnel with management experience, pilot skills, aircraft electronic and mechanical skills, plus supply, munitions, and other expertise were immediately identified for initial cadre training. However, personnel will need to be constantly trained throughout the life cycle of the F-16 aircraft. Trained replacement personnel are continually needed because of promotions, retirements, and many other reasons. With limited manpower resources available, active in-service personnel, local recruitment screened for training, and even foreign recruitment, Life Cycle Management (LCM) must constantly monitor and project manpower requirements in a timely manner to maintain uninterrupted support for the F-16 aircraft.

Therefore, after the discussion of challenges facing Bahrain Amiri Air Force, the BAAF should consider the methods in this thesis and adopt those which are most promising. The following points need the attention of the Bahrain Defense Force (BDF) and the BAAF in order to get the highest benefit from implementing the LCM in their system:

- The BDF and the BAAF should consider management practices which accommodate good LCM techniques and processes.

- The BAAF should consider adopting policies, procedures and rules for implementing LCM, consistent with its needs and circumstances- with the aim of improving cost and schedule performance.

- The BAAF must continue to find ways to monitor and collect data necessary for LCM to properly perform.

- The BAAF should establish an office to monitor, track, record, and forecast operating and support cost (O&S) of the F-16.

- The BDF should establish or assign an office for auditing to monitor, track and record all the O&S expenditures in the country and outside the country.

- The BAAF, represented by the maintenance department, should receive monthly and yearly reports containing details relating to F-16 expenditures in order to be up to date with any changes in terms of expenditures.

- The BAAF should identify the key O&S cost drivers for the F-16 Aircraft and use appropriate LCM practices to find ways to reduce and save assets.

- A plan should be put into place to forecast and identify the critical items that have direct impact on the readiness of the aircraft.

- A long run training plan needs to be put in place by reviewing, identifying and analyzing requirements in order to ensure adequate funding.

- The BAAF should monitor and project trained manpower requirements in a timely manner to maintain continuous support for the F-16 aircraft.

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APPENDIX A. CORE COST MODEL USED IN THE ANALYSIS

The Cost Oriented Resource Estimating Model (CORE) model is found on the Internet and was made available by the USAF. CORE is designed to provide a cost-estimating technique to be used to develop aircraft O&S cost estimates. CORE uses data available from standard USAF data systems (consistency). It allows the estimating techniques to vary as the program progresses through the phases of acquisition (flexibility), and it estimates all common O&S cost elements (completeness). It uses the format, cost element structure, and procedures generally required for milestone briefings (usefulness).

It is a high level O&S cost model but serves the purpose for this thesis. It allows for comparison analyses between variation between support concepts which is helpful in LCM and TOC evaluations. There are other, more detailed, models available for detailed cost analyses. Results using GENERIC information are presented below. The BDF considers this data to be highly sensitive. Squadron 2 has been adjusted to show possible savings discussed in Chapter V.

	O&S COST (GENERIC) for the BAAF F-16 Fleet	**Non – Adjusted**	**Adjusted**	
		Squadron 1	**Sqdn 2**	
	Aircraft Description	**F-16**	**F-16**	
4/28/1	**Economic Year Dollars**		**FYS2001**	
	Date	**04/28/01**	**04/28/01**	
***Inputs**				
Input No Code	**CAIG Description**	**F-16 Del. 1980**	**F-16 Del. 1990**	**Reference Information**
I	Program Factors			
F1	PAA	10	12	BAAF Input
F2	Crew Ratio	1	1	BAAF Input
F3	FH/PAA/YR	180	180	BAAF Input
F4	Pilots/Crew	1	1	BAAF Input
F5	Non-Pilot Officers/Crew		0	BAAF Input
F6	Enlisted/Crew	0	0	BAAF Input
F7	Pilot Training Factor	$ 493,003	$ 493,003	BAAF Input
F8	Non-Pilot Tng Factor	-	-	BAAF Input
F9	Enl Tng Fac	-	-	BAAF Input
				BAAF Input
II	Manpower Factors	340	186	BAAF Input
F10	PPE Officers	20	22	BAAF Input
F11	PPE Enlisted	320	164	BAAF Input
F12	PPE Civilians	0	0	BAAF Input
F13	BOS Officers	1	1	BAAF Input
F14	BOS Enlisted	26	13	BAAF Input
F15	BOS Civilians	8	4	BAAF Input
F22	Unit Staff Officers	4	4	BAAF Input
F23	Unit Staff Enlisted	14	14	BAAF Input
F24	Unit Staff Civilians	0	0	BAAF Input
F25	Security Officers	0	0	BAAF Input
F26	Security Enlisted	12	3	BAAF Input
F28	Other Staff Officers			BAAF Input
F29	Other Staff Enlisted			BAAF Input
F30	Other Staff Civilians			BAAF Input
F31	Civilian Pay	$ 46,493	$ 46,493	BAAF Input
				BAAF Input
III	Program Support Factors			BAAF Input
F35	POL/Dollars per FH	$ 744	$ 744	BAAF Input
F36	General Systems Spt/FH		$ 246	BAAF Input
F37	Systems Division Spt/FH		$ 129	BAAF Input
F38	Training Ordnance/FH	$ 44	$ 44	BAAF Input
F40	Depot Level Reparables (Fixed and Variable)/FH		$ 1,687	BAAF Input
F41	Support Equipment/PAA		$ 4,983	BAAF Input
F42	Flyaway Cost ($M)	$ 19	$ 19	BAAF Input
F43	Depot Maintenance/FH		$ 107	BAAF Input
F44	Depot Maintenance/PAA		$ 35,138	BAAF Input
F45	Contractor Logistics Support/FH		$ -	BAAF Input
F46	Contractor Logistics Support/PAA		$ -	BAAF Input
				BAAF Input
IV	Common Factors			BAAF Input
F48	Overall Officer Turnover	0.0656	0.0656	BAAF Input
F49	Non-rated Officer Turnover	0.0695	0.0695	BAAF Input
F50	Installation Support Non-Pay	$ 5,788	$ 5,788	BAAF Input
F55	Officers, Med Non-Pay	$ 3,022	$ 3,022	BAAF Input

F56	Enlisted, Med Non-Pay	$ 3,022	$ 3,022	BAAF Input
F57	Officers, Acquisition	$ -	$ -	BAAF Input
F58	Enlisted, Acquisition	$ -	$ -	BAAF Input
F59	Pilot Turnover	0.0481	0.0481	BAAF Input
F60	Non Pilot Aircrew Turnover	0.0736	0.0736	BAAF Input
F61	Enlisted Turnover	0.1025	0.1025	BAAF Input
F65	Class IV Mod (Safety) Equation /PAA	$ 59,778	$ 59778	CER per equation using Fly Away Cost above. CORE Model description.
F66	Officer Pay	$ 75,212	$ 75,212	BAAF Input
F67	Enlisted Pay	$ 38,189	$ 38,189	BAAF Input
F68	Non Aircrew Officer Training	$ -	$ -	BAAF Input
F69	Enlisted Non Aircrew Training	$ -	$ -	BAAF Input
				BAAF Input
V	Maintenance Personnel	300	153	BAAF Input
F70	Organizational Officers		6	BAAF Input
F71	Organizational Enlisted		147	BAAF Input
F72	Organizational Civilians			BAAF Input
F73	Intermediate Officers			BAAF Input
F74	Intermediate Enlisted			BAAF Input
F75	Intermediate Civilians			BAAF Input
F76	Ordnance Officers			BAAF Input
F77	Ordnance Enlisted			BAAF Input
F79	Other Officers			BAAF Input
F80	Other Enlisted			BAAF Input
F81	Other Civilians			BAAF Input
				BAAF Input
VI	Depot Maintenance File			BAAF Input
VII	Miscellaneous Factors			
SEC	**CAIG Description**	**Squadron Annual Value**	**Squadron Annual Value**	
1.0	Unit Mission Personnel	$13,724,720	$ 7,917,660	
1.1	Operations	$ 752,120	$ 902,544	
1.1.1	Aircrew	$ 752,120	$ 902,544	
1.2	Maintenance	$11,678,838	$ 6,065,055	
1.2.1	Organizational Maintenance	$11,678,838	$ 6,065,055	
1.2.1.1	Org Military Pay	$11,678,838	$ 6,065,055	
1.2.1.2	Org Civilian Pay	$ -	$ -	
1.2.2	Intermediate Maintenance	$ -	$ -	
1.2.2.1	Int Military Pay	$ -	$ -	
1.2.2.2	Int Civilian Pay	$ -	$ -	
1.2.3	Ordnance Maintenance	$ -	$ -	
1.2.3.1	Ord Military Pay	$ -	$ -	
1.2.4	Other Maintenance Personnel	$ -	$ -	
1.2.4.1	Other Military Pay	$ -	$ -	
1.2.4.2	Other Civilian Pay	$ -	$ -	
1.3	Other Mission Personnel	$ 1,293,762	$ 950,061	
1.3.1	Unit Staff	$ 835,494	$ 835,494	
1.3.1.1	Unit Staff Military Pay	$ 835,494	$ 835,494	
1.3.1.2	Unit Staff Civilian Pay	$ -	$ -	
1.3.2	Security	$ 458,268	$ 114,567	
1.3.2.1	Security Military Pay	$ 458,268	$ 114,567	
1.3.3	Other Msn.Pers.	$ -	$ -	
1.3.3.1	Other Military Pay	$ -	$ -	
1.3.3.2	Other Civilian Pay	$ -	$ -	

2.0	Unit Level Consumption	$ 5,130,000	$ 6,156,000	
2.1	POL/Energy Consumption	$ 1,339,200	$ 1,607,040	
2.1.1	POL	$ 1,339,200	$ 1,607,040	
2.1.2	Field Generated Electricity	$ -	$ -	
2.1.3	Commercial Electricity	$ -	$ -	
2.2	Consumable Material/Repair Parts	$ 675,000	$ 810,000	
2.2.1	Maintenance Material	$ 675,000	$ 810,000	
2.2.1.1	Aircraft Maintenance Material	$ 675,000	$ 810,000	
2.2.2	Operational Material	$ -	$ -	
2.2.3	Mission Support Supplies	$ -	$ -	
2.3	Depot Level Reparables	$ 3,036,600	$ 3,643,920	
2.4	Training Munitions / Expendable Stores	$ 79,200	$ 95,040	
2.5	Other Unit Level Consumption (Other Misc. Factor)			
3.0	Intermediate Maintenance (External to unit)	$ -	$ -	
3.1	Int Maintenance	$ -	$ -	
3.1.1	Int Maint Military Pay	$ -	$ -	
3.1.2	Int Maint Civilian Pay	$ -	$ -	
3.2	Consumable Material/Repair Parts	$ -	$ -	
3.3	Int Maint Other (Other Misc. Factor)			Line item provided to use with Other Misc. Factor (F133) if linked.
4.0	Depot Maintenance	$ 543,980	$ 652,776	
4.1	Overhaul/Rework	$ -	$ -	
4.1.1	Airframe	$ -	$ -	
4.1.2	Engine Rework	$ -	$ -	
4.1.3	Component Repair	$ -	$ -	
4.1.4	Support Equipment	$ -	$ -	
4.1.5	Modifications	$ -	$ -	
4.2	Other Depot Maintenance	$ -	$ -	
4.2.1	General Depot Support	$ -	$ -	
4.2.2	Second Destination Transportation	$ -	$ -	
4.2.3	Contracted Unit Level Support	$ -	$ -	
5.0	Contractor Support	$ -	$ -	
5.1	Interim Contractor Support	$ -	$ -	
5.2	Contractor Logistics Support	$ -	$ -	
5.3	Other Contractor Support (Other Misc. Factor)			
6.0	Sustaining Support	$ 647,606	$ 777,128	
6.1	Support Equipment Replacement	$ 49,826	$ 59,792	
6.2	Modification Kit Procurement/Installation	$ 597,780	$ 717,336	
6.3	Other Recurring Investment	$ -	$ -	
6.4	Sustaining Engineering Support	$ -	$ -	
6.5	Software Maintenance Support	$ -	$ -	
6.6	Simulation Operations	$ -	$ -	
6.7	Other Sustaining Support (Other Misc. Factor)			
7.0	Indirect Support	$ 4,956,860	$ 2,827,399	
7.1	Personnel Support	$ 1,346,290	$ 889,006	
7.1.1	Medical Support	$ 1,109,156	$ 604,444	
7.1.1.1	Medical Support Military Pay	$ -	$ -	
7.1.1.2	Medical Support Civilian Pay	$ -	$ -	
7.1.1.3	Medical Support Non pay/Material	$ 1,109,156	$ 604,444	

7.1.2	Specialty Training	$ 237,134	$ 284,561	
7.1.2.1	Pilot Training	$ 237,134	$ 284,561	
7.2	Installation Support	$ 3,610,570	$ 1,938,393	
7.2.1	Base Operating Support Personnel	$ 1,440,070	$ 757,641	
7.2.1.1	BOS Military Personnel	$ 1,068,126	$ 571,669	
7.2.1.2	BOS Civilian Personnel	$ 371,944	$ 185,972	
7.2.3	Installation Support Non-Pay Personnel	$ 2,170,500	$ 1,180,752	
		F16 (1980)	**F16 (1990)**	
	CORE Squadron Total ($/YR)	**$25,003,166**	**$18,330,962**	**$43,334,128**
		F16 (1980)	**F16 (1990)**	
	$ Per Flight Hour	**$ 13,891**	**$ 8,487**	**$ 11,189**
	$/FH Breakouts:	**F16 (1980)**	**F16 (1990)**	
	Fuel ($/FH)	$ 744	$ 744	
	Personnel + Indirect ($/FH)		$ 4,975	
	Maintenance ($/FH)	$ 2,768	$ 2,768	
	$ Per Flight Hour	**$ 13,891**	**$ 8,487**	**$ 11,189**
		F16 (1980)	**F16 (1990)**	
	CORE Squadron Total ($/YR)		**$18,330,962**	**$43,334,128**
	$/FH Breakdown	**F16 (1980)**	**F16 (1990)**	
	Fuel	$ 744	$ 744	
	Personnel	$ 7,625	$ 3,666	
	Indirect Support Pers	$ 2,754	$ 1,309	
	Maintenance	$ 2,408	$ 2,408	
	Sustain Support	$ 360	$360	
	Total	**$ 13,891**	**$ 8,487**	**$11,189**
	Fuel and Maintenance Cost Per Flight Hour		**F16 (1990)**	
	Fuel	$ 744	$ 744	
	Maintenance	$ 2,408	$ 2,408	
	Sustain Support	$ 360	$ 360	
	Total	$ 3,512	$ 3,512	
	Type Aircraft	**F16 (1980)**	**F16 (1990)**	
	Fuel	$ 1.3	$1.6	
	Maintenance	$ 4.3	$5.2	
	Sustaining Support	$ 0.6	$0.8	
	Personnel	$ 13.7	$7.9	
	Indirect Support Personnel		$2.8	
	Squadron Total ($/YR) ($M)		**$18.3**	
	Remaining FH of Service		72240	
	Remaining Years of Service		33	
	Squadron Total ($M)	**$ 575.07**	**$ 604.92**	
	BAAF Total ($M) for Remaining Life of F16 Fleet			

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